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ABSTRACT

This course is one of several subcourses that make up the entire Army correspondence course on wheeled vehicle maintenance. The subcourse is designed to provide the student with information about the operation, malfunction diagnosis, maintenance, and repair of wheeled vehicle electrical systems. It provides the basic theory, and also includes on-the-job task assignments. The subcourse is divided into eight lessons covering the following topics: introduction to automotive electricity; automotive batteries; fundamentals of electrical testing equipment; generating systems; cranking systems; introduction to ignition systems; repair of ignition systems; and electrical systems. Each lesson contains objectives, text, task assignments, and review exercises. Answers for the exercises are provided after the final lesson, along with an examination and application task test. This subcourse is designed for student self-study, but could be used in small group learning situations. (KC)

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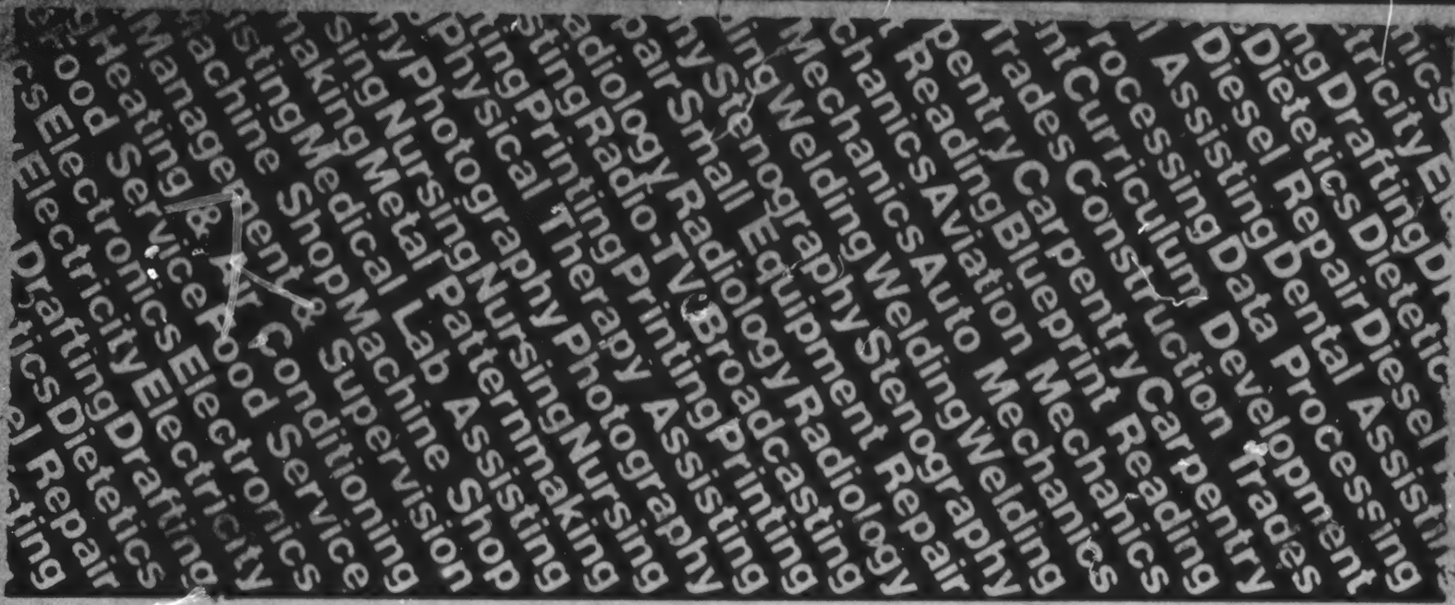

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# Military Curriculum Materials for Vocational and Technical Education

CE031194

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## WHEELED VEHICLE ELECTRICAL SYSTEMS

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY
1960 KENNY ROAD · COLUMBUS, OHIO 43210

# MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

# Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

**Project Staff:**

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

# What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

# How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

## CURRICULUM COORDINATION CENTERS

**EAST CENTRAL**
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Springfield, IL 62777
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Honolulu, HI 96822
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# The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

**FOR FURTHER INFORMATION ABOUT**
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Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
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# Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

SCHOOL CODE
091
SUBCOURSE ED
HB6303 6

# U.S. Army Training Support Center

## Fort Eustis, Virginia

☆ACCP

WHEELED VEHICLE ELECTRICAL SYSTEMS

# ARMY CORRESPONDENCE COURSE PROGRAM

# -- IMPORTANT --

# STUDY THIS SHEET

*before beginning the subcourse*

## *General*

Your cooperation in following these instructions will

--enable you to make the maximum rating commensurate with your ability.
--help us to process your lessons promptly and efficiently.

Scan the CHECKLIST OF TEXTS AND MATERIALS FURNISHED.
Scan the INTRODUCTION to the subcourse.

## *Procedure*

- --Beginning with Lesson 1, scan the LESSON ASSIGNMENT SHEET. It lists the lesson title, lesson objective, credit hours required, texts required, and suggestions.
- --When the words STUDY TEXT follow the Lesson Assignment Sheet, the information you must digest is found in a text(s), memorandum, pamphlet, and/or other separate material(s).
- --When the words STUDY GUIDE AND ATTACHED MEMORANDUM follow the Lesson Assignment Sheet, the information you must digest is either
    - --found in texts and in this subcourse booklet, or
    - --found entirely in this booklet.
- --When you are referred to a paragraph or an illustration in a manual, turn to the specified paragraph at once and scan or study the text assignment as directed. Continue this procedure until you reach the LESSON EXERCISE.

## *Lesson Exercise*

- --Study and answer each question.
- --CAUTION: Check to insure that all questions have been answered.
- --Your answers MUST be based on subcourse materials, NOT on your experience or opinions.

## *Assistance*

If you require explanation or clarification of subcourse materials or questions, write to the U. S. Army Ordnance Center and School, ATTN: Course Development Directorate. Constructive comments are appreciated.

Include NAME and SOCIAL SECURITY ACCOUNT NUMBER on all correspondence.

1A

**Course Description:**

This course is one of several subcourses that make up the entire correspondence course on wheeled vehicle maintenance. The subcourse is designed to provide the student with information about the operation, malfunction diagnosis, maintenance, and repair of wheeled vehicle electrical systems. It provides the basic theory, and also includes on-the-job task assignments.

The subcourse is divided into eight lessons with objectives, task assignments, and review exercises.

Lesson 1 - Introduction to Automotive Electricity. An explanation of the fundamentals of AC and DC electricity as it applies to automotive equipment.

Lesson 2 - Automotive Batteries. An explanation of the construction, operation, and maintenance of automotive batteries.

Lesson 3 - Fundamentals of Electrical Testing Equipment. An explanation of the purpose, construction, and operation of electrical testing equipment.

Lesson 4 - Generating Systems. An explanation of the principles of AC and DC generators and regulators; the inspection, testing, and repair of generating components as they apply to the organizational wheeled vehicle mechanic; and the replacement of repair parts.

Lesson 5 - Cranking Systems. An explanation of the application of the fundamentals of electricity to starting system components; inspection, testing, and repair of of starting system components; and the replacement of repair parts.

Lesson 6 - Introduction to Ignition Systems. An explanation of the application of the fundamentals of electricity to the components of a wheeled vehicle battery ignition system.

Lesson 7 - Repair of Ignition Systems. A description of how to inspect, test, adjust, repair ignition systems; ignition timing; and the replacement of repair parts.

Lesson 8 - Electrical Systems. An explanation of the principles of vehicle lighting and electric gage system; reading of automotive electrical schematics; inspection, testing, adjustment, and repair of electrical system components; and the replacement of repair parts.

This subcourse is designed for student self-study, but could be effective in small group learning situations. Each lesson contains objectives, text, and review exercises. Answers for the exercises are provided after the final lesson, along with an examination and application task test.

WHEELED VEHICLE ELECTRICAL SYSTEMS
63B203

Correspondence Course 8-13

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**Developed by:**

United States Army

**Development and Review Dates:**

January 1976

**Occupational Area:**

Engine Mechanics

**Print Pages:**

398

**Availability:**

ERIC
National Center Clearinghouse

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**Suggested Background:**

None

**Target Audiences:**

Grades 10-Adult

**Organization of Materials:**

Text, Objectives, Exercises, Examination

**Type of Instruction:**

Individualized

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| Type of Materials: | No. of Pages: | Average Completion Time: |
|---|---|---|
| Lesson 1 - Introduction to Automotive Electricity | 54 | 3 Hours |
| Lesson 2 - Automotive Batteries | 46 | 2 Hours |
| Lesson 3 - Fundamentals of Electrical Testing Equipment | 46 | 4 Hours |
| Lesson 4 - Generating Systems | 62 | 4 Hours |
| Lesson 5 - Cranking Systems | 36 | 3 Hours |
| Lesson 6 - Introduction to Ignition Systems | 30 | 2 Hours |
| Lesson 7 - Repair of Ignition Systems | 38 | 4 Hours |
| Lesson 8 - Electrical Systems | 44 | 4 Hours |
| Exercise Response List | 39 | |

**Supplementary Materials Required:**

None

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The Ohio State University

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**ENLISTED MOS**

**CORRESPONDENCE/OJT COURSE**

# ORDNANCE SUBCOURSE 63B203
# WHEELED VEHICLE ELECTRICAL SYSTEMS

## LESSON 1
## INTRODUCTION TO AUTOMOTIVE ELECTRICITY

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND
(IMPORTANT INFORMATION ON BACK COVER)

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## LESSON EXERCISE QUESTIONS

Instructions for use of the answer sheet:

1. The procedure by which you will answer the exercise questions in this subcourse is probably new to you. The information is presented in a programed instruction format where you immediately know whether or not you have answered the questions correctly. If you have selected an incorrect answer, you will be directed to a portion of the study text that will provide you with additional information.

2. To use this system proceed as follows:

a. Arrange this subcourse booklet and your answer sheet (on reverse side of response list cover) so that they are convenient. Each exercise question has three choices lettered a, b, and c. Your answer sheet has three groups of numbers for questions 1 through 200. The numbers indicated for each question represent the a, b, or c choices.

b. Read the first exercise question and select the choice you think answers the question correctly. Go to the question 1 area of your answer sheet and circle the 3-digit number that corresponds with the choice you selected.

c. After you have identified the 3-digit number, locate it in the exercise response list. If you selected the right choice, the first word of the response will be "CORRECT." This tells you that you have answered the question correctly. Read the rest of the response which tells why your choice was correct and then go to the next question.

d. If the word "CORRECT" is NOT the first word of the response, you have selected the wrong answer. Read the response and then turn to the area in your study text that is mentioned. There you will find the information necessary for you to make another choice. Line out the incorrect 3-digit response on your answer sheet.

e. After you have reread the reference, select another answer and circle the 3-digit response for that choice. Again check the number of this second choice with the response list to see if your choice is now correct and to obtain more information about your choice. If your second choice is still not correct, line out the 3-digit response on the answer sheet and continue until the correct answer is selected. When you have answered all of the questions in an exercise, count the number of lined out responses and see how well you did.

f. You will notice that the lesson exercise question numbers continue consecutively from lesson to lesson. This allows you to use one answer sheet for the entire subcourse.

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**IMPORTANT** - Study these directions before going further.

## DIRECTIONS FOR THE STUDENT

1. Congratulations. You are starting a new and different type of self-training correspondence course called correspondence/OJT. It is different from regular subcourses because it has tasks to be practiced on the job in addition to the usual lessons to be studied. This way, you can learn both the job skills and the job knowledge and become completely qualified in the subcourse matter.

2. Of course, you must be able to get to the equipment to practice these tasks. Some of you may not be able to do this. This is why you were asked to pick one of two options, or ways, that you wanted to take the subcourse.

a. If you are enrolled in the correspondence only option, you will study the lessons but you will not practice the tasks on the equipment. This means you will learn only the job knowledge of the subcourse. You will have to practice the job tasks sometime later when you can get to the equipment in order to learn the job skills. You will test yourself during each lesson by answering the lesson exercise questions using your answer sheet. Then you will be tested at the end of the whole subcourse by taking the enclosed multiple choice examination.

b. If you are enrolled in the correspondence/OJT option, you will do the whole subcourse. You will study all the lessons and practice all the tasks listed in each study text on the equipment. This way you will learn both the knowledge and the skills of the subcourse. Then you will be completely qualified in the part of your military occupational specialty (MOS) that is covered by this subcourse. You will test yourself after each lesson by answering the lesson exercise questions using your answer sheet. And you will also take a subcourse multiple choice examination. However, in addition to these tests, you will take an application task test after finishing the subcourse examination. This application task test will be sent to your unit commander who will see that you are tested on the job tasks. It is important that you practice the tasks while you are studying the lessons so that you will be ready for the task test when you finish the subcourse.

c. You can understand that it is important to remember which of the two options you are enrolled in because the work you must do and the tests you must take will depend upon your option.

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3. This subcourse is one of several subcourses that make up the entire enlisted MOS correspondence/OJT course. If you are enrolled in the entire course, you will take this and all the other subcourses in order. If you are not enrolled in the entire course, then you will only take this and any other subcourses you asked for. Of course, you cannot become qualified in the complete MOS job unless you take the entire course. If you want to take the entire course later, you will be given credit for the subcourse(s) you have already passed.

4. Please check this subcourse packet to make sure that you have the following things:

a. A lesson booklet for each lesson listed in the introduction of lesson 1.

b. A lesson exercise response list.

c. A multiple choice examination.

If any of these things are missing, please let us know right away.

5. If you are enrolled in the entire enlisted MOS correspondence/OJT course you must finish at least 70 credit hours or three subcourses each enrollment year. Your enrollment year begins the day you receive your first subcourse. If you are enrolled in certain subcourses only, you must finish each subcourse within 6 months after you receive it. However, you should finish each subcourse as quickly as you can so that you will qualify earlier for promotions.

6. You must study the subcourse material starting with lesson 1 and progress through the rest. Beginning with lesson 1, scan the lesson assignment sheet. It lists the lesson title, credit hours assigned to the lesson, lesson objective, study assignment, and suggestions.

a. Go through the lesson exactly as you are told by the study assignment and the suggestions in the lesson assignment. Also follow any directions given throughout the study text.

b. Read the lesson. Study any portion that you do not understand. Answer the exercise questions as you encounter them. Then practice the job tasks on the equipment.

# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## ORDNANCE SUBCOURSE NUMBER 63B203
## WHEELED VEHICLE ELECTRICAL SYSTEMS
(27 Credit Hours)

## INTRODUCTION

The electrical systems of military wheeled vehicles are well designed and well constructed. With a few exceptions, they are much like the systems used on civilian-type vehicles. Probably the two biggest differences are that 24-volt systems are used on military vehicles and 6- or 12-volt systems on civilian types. Also, the electrical systems on most military vehicles are waterproof.

While these systems are well made they still give some trouble, and they are one of the things that most wheeled vehicle repairmen understand the least.

One of your jobs will be the maintenance of these systems. While it is not difficult, it does take some "know-how."

This subcourse is designed to familiarize you with these systems. It will also provide you with the required "know-how." It consists of eight lessons, a subcourse examination, and an application task test.

The subcourse is organized as follows:

Lesson 1 Introduction to Automotive Electricity
Scope—An explanation of the fundamentals of AC and DC electricity as it applies to automotive equipment.

Lesson 2 Automotive Batteries
Scope—An explanation of the construction, operation, and maintenance of automotive batteries.

**Lesson 3** Fundamentals of Electrical Testing Equipment
Scope—An explanation of the purpose, construction, and operation of electrical testing equipment.

**Lesson 4** Generating Systems
Scope—An explanation of the principles of AC and DC generators and regulators; the inspection, testing, and repair of generating components as they apply to the organizational wheeled vehicle mechanic; and the replacement of repair parts.

**Lesson 5** Cranking Systems
Scope—An explanation of the application of the fundamentals of electricity to starting system components; inspection, testing, and repair of starting system components; and the replacement of repair parts.

**Lesson 6** Introduction to Ignition Systems
Scope—An explanation of the application of the fundamentals of electricity to the components of a wheeled vehicle battery ignition system.

**Lesson 7** Repair of Ignition Systems
Scope—A description of how to inspect, test, adjust, repair ignition systems; ignition timing; and the replacement of repair parts.

**Lesson 8** Electrical Systems
Scope—An explanation of the principles of vehicle lighting and electric gage system; reading of automotive electrical schematics; inspection, testing, adjustment, and repair of electrical system components; and the replacement of repair parts.

**Examination and application task test.**
Scope—The examination is designed to test the student's overall knowledge of the subject material covered in the subcourse. The application task test is designed to test the correspondence/OJT option student's ability to perform tasks associated with the subject material presented in the subcourse.

# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

**Ordnance Subcourse** 63B203. . . Wheeled Vehicle Electrical Systems

**Lesson** 1 . . . . . . . . . . . Introduction to Automotive Electricity

**Credit Hours** . . . . . . . . . Three

**Lesson Objective** . . . . . . . After studying this lesson you will be able to:

1. State commonly known facts concerning the everyday use of electricity.
2. Describe the atom and explain its relation to matter.
3. Describe an electric current.
4. State the characteristics of conductors and insulators.
5. Define the terms "current," "voltage," and "resistance" and state their relationship.
6. Describe the difference between alternating and direct current.
7. Define magnetism and state the laws of magnetic repulsion and attraction.

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8. Define induction and state the factors affecting the amount of induction.
9. Identify common symbols used in schematic diagrams of automotive electrical systems.
10. Identify common types of electrical circuits.
11. Define common descriptive terms of circuit defects in automotive electrical systems.

| | |
|---|---|
| **Study Assignment** . . . . . . . | Study the text that follows. The electrical system is a vital part of a military vehicle. It is involved in the starting, operating, heating, lighting, ventilating, and signaling. Safety and dependability of the vehicle are dependent on the electrical system. Study the lesson carefully so you will be able to understand and service the electrical system. |
| **Materials Required** . . . . . . | **All students:** Exercise response list and answer sheet.<br>**Correspondence/OJT option students:** See appendix B. |
| **Suggestions** . . . . . . . . . . | Study all printed material and illustrations in the order presented. Consider all comparisons from the viewpoint presented in the lesson. |

## STUDY TEXT

## SECTION I. INTRODUCTION TO AUTOMOTIVE ELECTRICITY

1. INTRODUCTION. During the past one hundred years, electricity became more important to man as each year went by. Today, in our homes, we depend on it for light, heat, and music. It provides power to operate water pumps, tools, kitchen appliances, and many other household items. Outside of the home, we also depend on electricity for many things. The family car is a good example. It uses electricity for lights, music, heat, and to make the engine run.

a. Most of the time we simply flip a switch to make electricity work for us. In a house you use a switch to turn the lights or radio on. You do the same thing in your car. If the electricity does not do the work it is supposed to do when you move the switch, it is usually necessary to get help from a repairman.

b. You, as a wheeled vehicle mechanic, are the repairman who will be called upon when the electrical systems of Army wheeled vehicles don't work. You will need to find out what is wrong first, and then repair the trouble.

c. Each of us realizes how much we depend on electricity in our day-to-day activity. Without it there would be no artificial electric lights, heat, refrigeration, etc.

d. By the same token, the military vehicles you will be working on must have electricity for many purposes such as ignition, lights, blower fans, etc.

e. Therefore, it is easy to see that a wheeled vehicle mechanic should have a working knowledge of electrical circuits so he can keep the equipment in good operating condition.

f. To do this you will have to know what electricity is, how it is used, and how electrical items work. This lesson will give you the information you need to understand what electricity is and how it can be made to do work for us.

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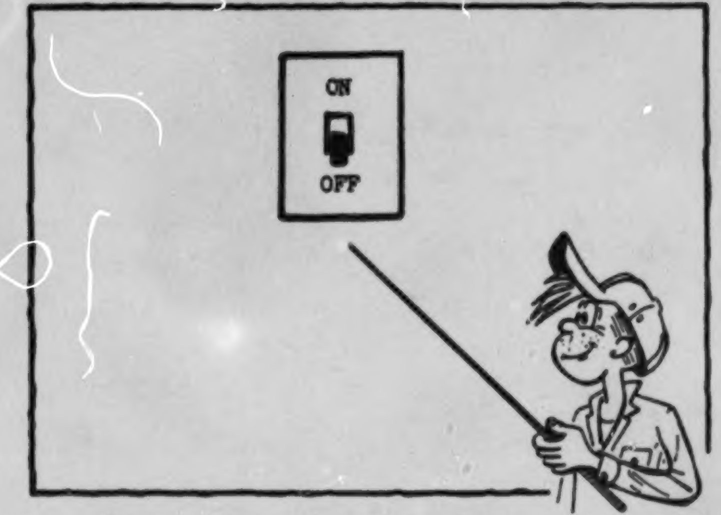
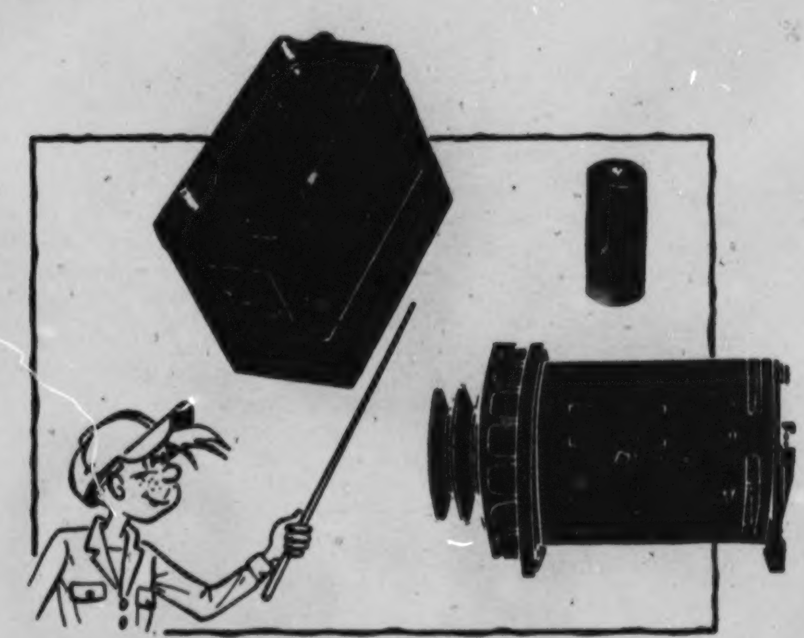
2. COMMON KNOWLEDGE OF ELECTRICITY. To begin with let's review some of the things that are commonly known about electricity.

a. Normally, closing a switch is all that is needed to make it work.



b. It is available from several sources, such as flashlight batteries, storage batteries like the ones used in cars, and generators ranging from hydroelectric plants to car generators.



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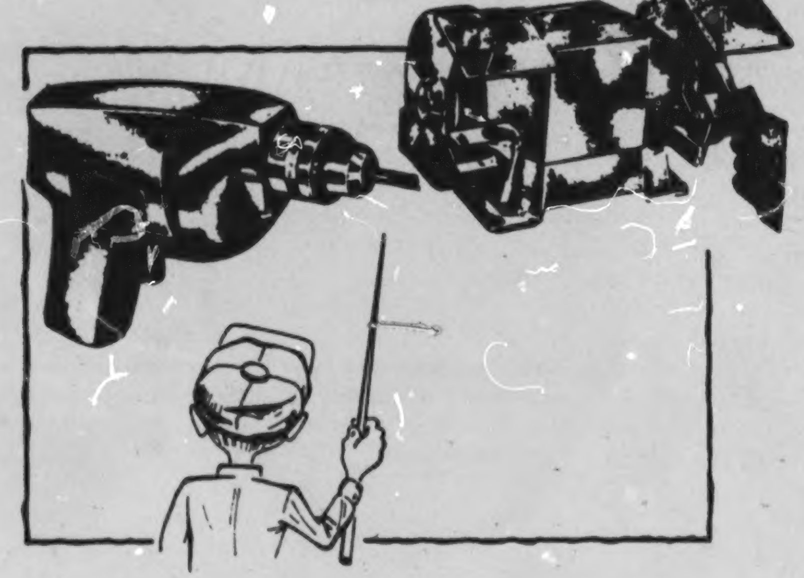
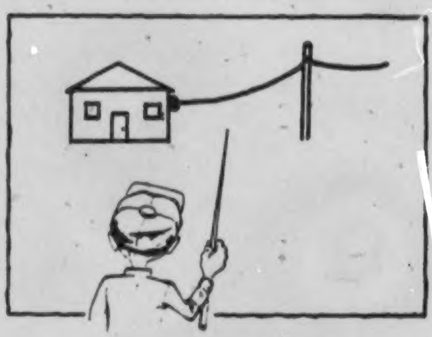
c. We know electricity can cause a shocking sensation if it touches our body. We also know that as the amount of electricity increases, the shock we feel gets worse.

d. It can do work. Today it is one of our most important sources of energy.

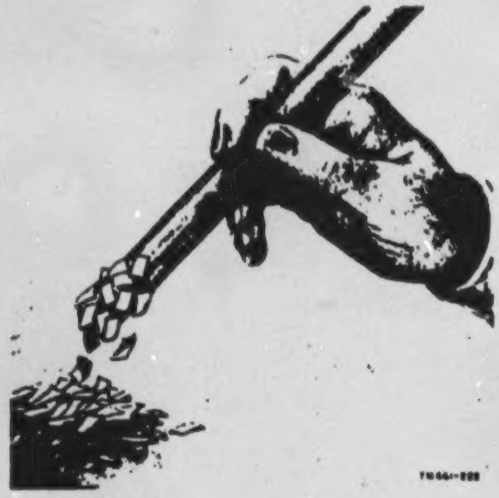


e. We also know that wires or some other form of connections are needed between the source of electricity and the appliance to be operated.

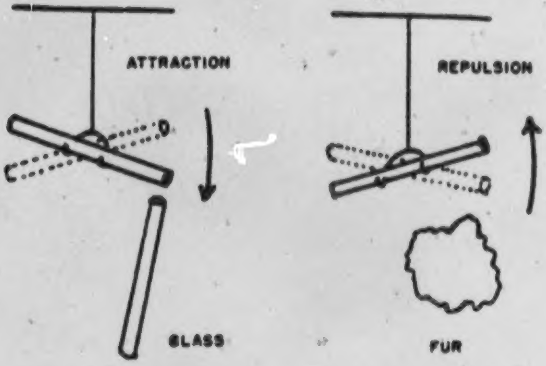


3. **SCOPE OF THIS LESSON.** The complete study of electricity covers a wide and complicated field. Even then it leaves a lot of questions unanswered as there is still a lot to learn about electricity. This lesson is not designed to teach you all there is to know about the subject. What is intended though is that the material presented will enable you to understand automotive electricity to a point where you know what it is, what it is supposed to do, how it does it, and how to determine what is wrong if it isn't doing it properly.

4. **HISTORICAL MILESTONES OF ELECTRICITY.** The word electricity comes from the Greek word elektron which means amber. History tells us that more than 2,500 years ago a famous Greek named Thales found out that electricity existed. Thales noticed that after he rubbed a piece of amber with a woolen cloth, the amber would attract lightweight items like dust, straws, feathers, and small pieces of lint. This was because the amber had become electrically charged. Thales knew nothing about electricity so he thought that this only happened with amber.



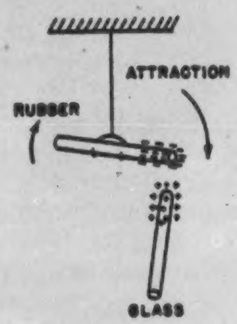
a. In 1733, a Frenchman named Dufay found out that if a piece of glass was rubbed with cat's fur, the glass and cat fur would become charged or electrified. He also found out that the charged glass would attract certain things that the cat's fur would repel or push away. From this experiment he correctly decided that there were two kinds of electricity that were directly opposite.

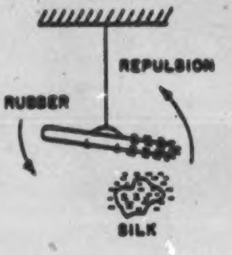


15

b. Benjamin Franklin decided that the two kinds of electricity should be called POSITIVE and NEGATIVE. These terms are still used today and you will hear them used often in discussions about automotive electricity. They are also commonly referred to as plus and minus and are many times shown as (+) and (-). Positive, plus, and (+) refer to one kind of electrical charge, while negative, minus, and (-) refer to the opposite charge.

c. It has been found that like charges repel each other while unlike charges attract. Thus, if we have two items that have positive charges they will repel or push away from each other. The same action occurs if the items have negative charges. On the other hand, if we have one item that contains a positive charge and another item with a negative charge they will attract or pull together.

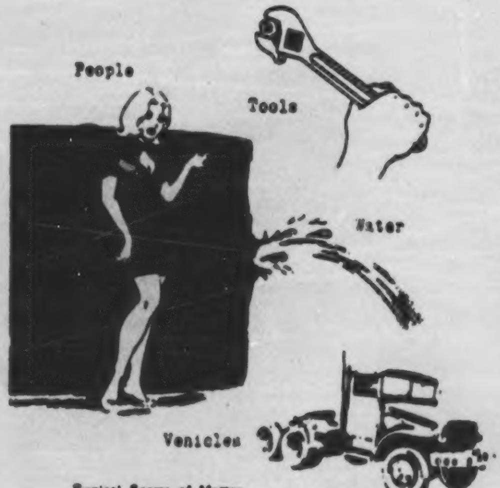




d. For many years it was believed that only such things as glass, amber, silk, and cat's fur could be electrified or charged. We know now, however, that under certain conditions all substances can be electrified.

## 5. MATTER AND THE ATOM.

The mystery of electrification and the positive and negative charges was finally solved by studying the construction of matter. Matter is defined as any substance that has weight and occupies space. Examples of matter are the air we breathe, water, cars, clothing, etc. For you to obtain an idea of what electricity really is, and so you will be able to predict its action in automotive electrical circuits, we will need to take a brief look at the construction of matter.



Typical Forms of Matter

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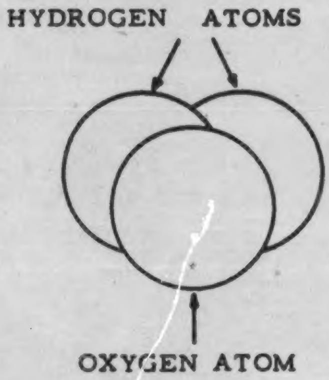
a. Imagine that you could take some form of matter, such as a rock, and break it down into the smallest particles that it can exist in and still be the original substance that you started with. These tiny particles are called molecules. Actually, you would not be able to do this, for as you continued to crush the rock you would finally end up with particles of dust. Just one of the small dust particles would contain thousands of molecules.

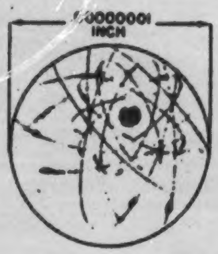
b. Scientists have discovered that a molecule of any form of matter contains one or more building blocks called atoms. Each atom is an element. There are about 100 different kinds of atoms or elements. Some are metal such as copper, iron, and gold. Others are nonmetallic such as oxygen, hydrogen, and sulfur. While an element by itself is matter, different kinds of matter are also formed by mixing various elements. When two or more elements are mixed properly, we get matter that is called a compound. For instance, a molecule of water is formed when two hydrogen atoms are joined with one oxygen atom. Therefore, water is a compound.



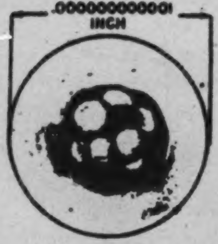
WATER MOLECULE

c. The secret of electrification was not discovered until scientists finally realized that atoms are made up of three smaller particles. These particles are called electrons, protons, and neutrons. The protons have a positive charge, electrons have a negative charge, and neutrons are neutral or have no charge. Let's take a look at what the scientists believe the atom looks like.

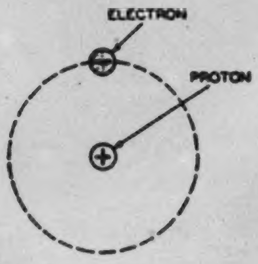
(1) As an example we will use one atom of the element aluminum. Imagine that we have a powerful magnifying glass that is able to magnify the atom so it appears to be one hundred million times larger than its actual size. This makes it look to be about 1 inch in diameter. We can now easily see that the atom has a central body which is called the nucleus. After careful study we can also determine that there are 13 smaller particles, called electrons, rapidly circling around the nucleus, each one moving in a different path.



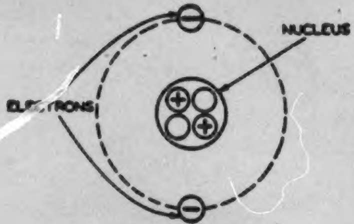
(2) Now imagine that we are able to magnify the aluminum atom even more so that only the nucleus fills the viewing area. The nucleus now looks like a bunch of grapes. It actually consists of 27 particles bound tightly together, 13 of which are protons and and the other 14 are neutrons.


.000000000001 INCH

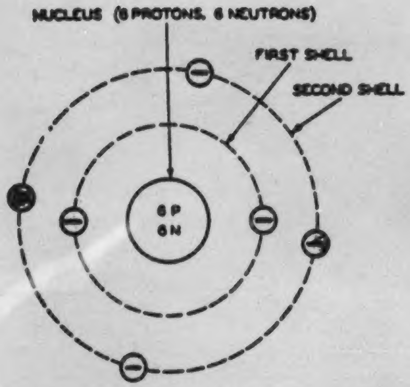
(3) Every atom in any one element is exactly alike. They have the same number of electrons, protons, and neutrons, will all be the same size, and will all weigh the same. On the other hand, atoms from different elements are completely different. The atoms from each element contain an equal number of electrons and protons. Recall that our aluminum atom contained 13 electrons and 13 protons.


ELECTRON
PROTON

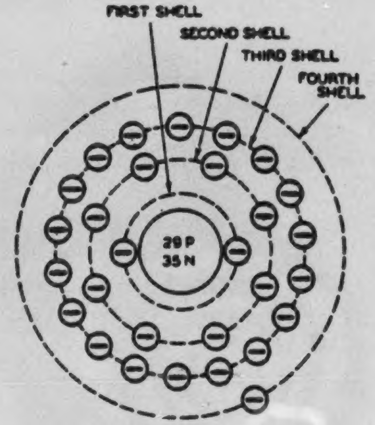
HYDROGEN ATOM


NUCLEUS
ELECTRONS

HELIUM ATOM

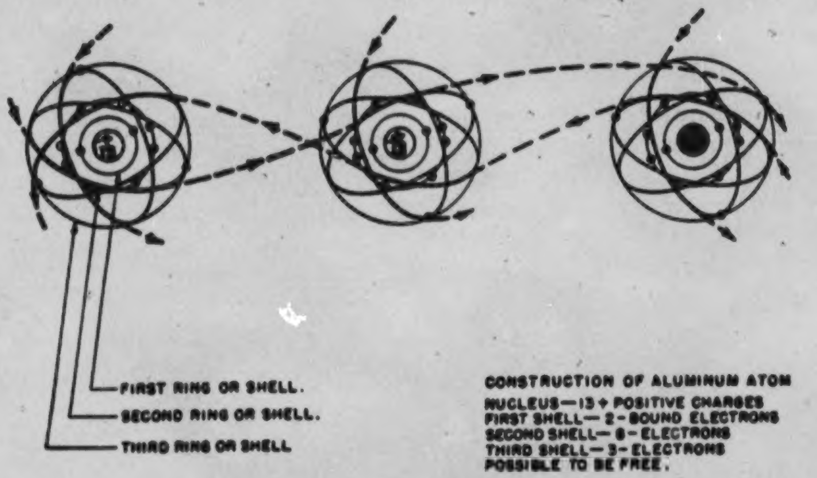

NUCLEUS (6 PROTONS, 6 NEUTRONS)
FIRST SHELL
SECOND SHELL
6 P
6 N

CARBON ATOM


FIRST SHELL
SECOND SHELL
THIRD SHELL
FOURTH SHELL
29 P
35 N

COPPER ATOM

(4) Now let's go back to our magnifying glass and reduce its power so that we can see several atoms of aluminum in the viewing area. You can now notice that the electrons moving in the outer circles of the atoms do not always stay in the same atom. Instead, they move haphazardly from atom to atom. They are called free electrons and, as you will see, they are the ones we are most interested in for our study of automotive electricity.

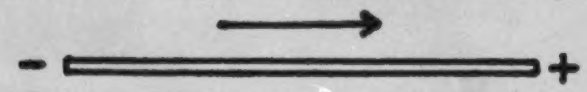

FIRST RING OR SHELL.
SECOND RING OR SHELL.
THIRD RING OR SHELL
CONSTRUCTION OF ALUMINUM ATOM
NUCLEUS—13 + POSITIVE CHARGES
FIRST SHELL— 2 - BOUND ELECTRONS
SECOND SHELL— 8 - ELECTRONS
THIRD SHELL— 3 - ELECTRONS
POSSIBLE TO BE FREE.

(5) As some of the free electrons move out of their orbit (path) the atom will have more protons than it does electrons. Since the protons have a positive charge this will give the atom a positive charge. If the free electrons move to an atom that already has enough electrons, the atom will be negatively charged since it will have a surplus of electrons. A negatively charged body repels electrons while the positively charged body will attract electrons.

6. ELECTRON MOTION. In automotive electricity we are most interested in the mass movement of electrons through an item such as a wire. Such a movement of electrons is called an ELECTRIC CURRENT just as the flow of water in a stream is called a current.

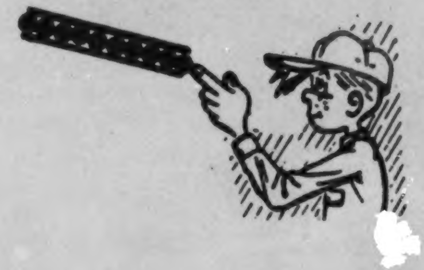
a. When there is a surplus of electrons at one end of a wire and a shortage of electrons at the other end, electrons will flow from the surplus to the shortage. Since a surplus of electrons is a negative charge and the shortage a positive charge, electric current then flows from negative to positive.

Direction of Current Flow



b. When an electron leaves the negative source this same electron does not just speed through the wire. Instead it strikes another electron and knocks it loose from its atom. This loosened electron then strikes another electron knocking it free. As one electron knocks another loose, it replaces the one it knocked out. This occurs as a chain reaction throughout the entire length of the wire.

c. To illustrate this action imagine that you have a pipe filled with marbles from end to end. If you push a marble in one end of the pipe one marble will pop out the opposite end. As soon as the marble presses on the column of marbles its movement is transmitted all the way through the pipe. The pipe is comparable to a wire and the marbles to electrons.



Note. - Complete exercises number 1 through 6 before continuing to section II.

1. Electricity is most important to us

   a. for its heating qualities.
   b. because of its ability to produce magnetism.
   c. as a source of energy.

2. Which form of matter contains more than one element?

   a. Copper
   b. Sulphur
   c. Water

3. The nucleus of an atom contains particles with

   a. negative and positive charges.
   b. positive and neutral charges.
   c. neutral and negative charges.

4. Which statement pertaining to electrical charges is true?

   a. Like charges attract while unlike charges repel
   b. Negative, minus, and (-) refer to one kind of charge
   c. The only things that can be electrically charged are items like glass, amber, silk, and fur

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5. If an atom has 12 electrons, 13 protons, and 14 neutrons it will have a

a. positive charge.
b. negative charge.
c. neutral charge.

6. Current is a flow of

a. atoms.
b. electrons.
c. protons.

## SECTION II. FUNDAMENTALS OF ELECTRICAL CIRCUITS

7. CONDUCTORS. Because atoms from different elements are not all alike, they can have a lot to do with the automotive electrical system. Electrical current will flow through some materials easily while in others practically no electrons will flow. If current flows through a material easily the material is called a CONDUCTOR.

a. A good conductor is a material that has a large number of free electrons. All metals are conductors of electricity, but some are better conductors than others. Examples of good conductors are silver, copper, and aluminum. Silver is a better conductor than copper, but copper is more widely used because it is cheaper. Since aluminum is light it is used as a conductor where weight is a major consideration.

b. The ability of a material to conduct electricity also depends on its size. The greater its diameter and the shorter its length, the better it conducts. Conductors may be in the forms of bars, tubes, or sheets, but the most common form is wire. Many sizes of wire are used, from the fine hair-like wire in sensitive measuring instruments to the large bar-like wire used for carrying high current in electric power generating plants.

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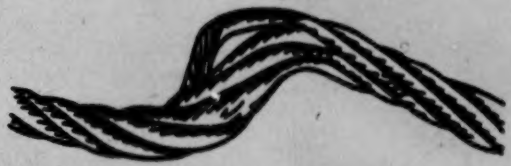
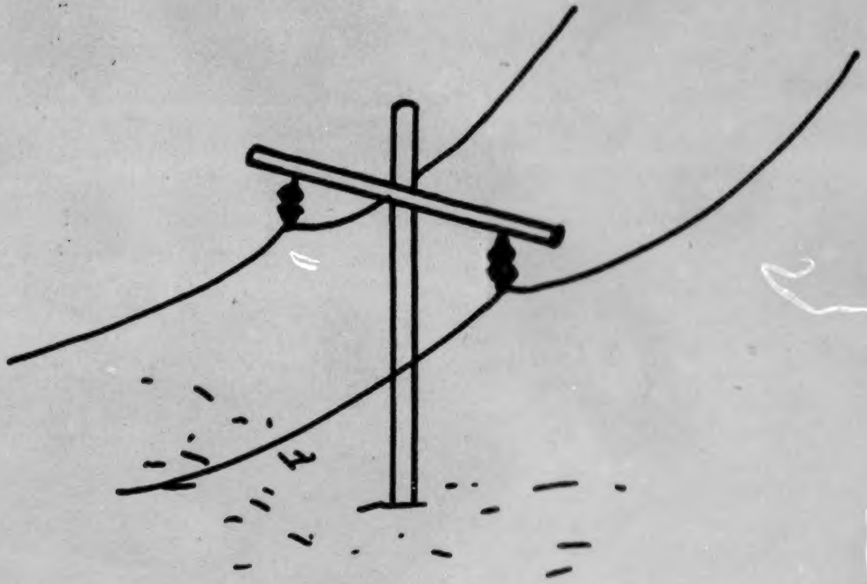
c. Most wire conductors that you will be working with on automotive vehicles are stranded wires. A stranded wire consists of many small wires twisted together to make one conductor. This makes them very flexible so they can be bent and fitted around vehicle components without breaking.

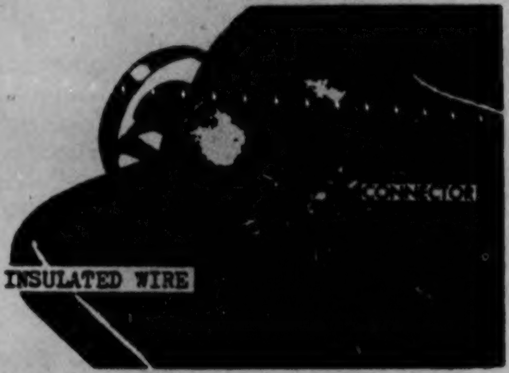


8. INSULATORS. If a material has so few free electrons that it blocks electron flow it is called an INSULATOR. No material known is a perfect insulator, but there are some which are such poor conductors that for all practical purposes they are classed as insulators. Examples of some insulators are porcelain, glass, air, rubber, oil, bakelite, and certain kinds of enamel and varnish.

a. Insulators are used to make sure that the flow of electrons does not stray out of the path that has been provided with conductors. An example of this is the insulator used to anchor electric lines to their supporting poles. The insulators block the electrons to prevent them from flowing into the pole and into the ground.

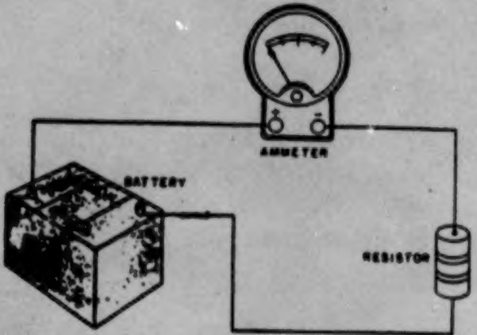


b. In automotive vehicles, insulators must also be used to keep the flow of electrons or current in the proper path. The wire conductors are covered with insulating material such as rubber, cotton, plastic, or enamel. Hard insulating materials such as fiberboard and bakelite are used in places like the ignition system and switches where parts need to be mounted securely by a rigid insulator.



9. CURRENT. Electric current, like the flow of water, can be measured. Water flowing in a pipe may be measured by the number of gallons of water that flow per minute. Electric current is measured by units called AMPERES. It takes more than 6 billion billion electrons moving past a given point in one second to make up one ampere.

a. A device called an AMMETER is used to measure amperes. The use of the ammeter is covered in detail in later lessons.

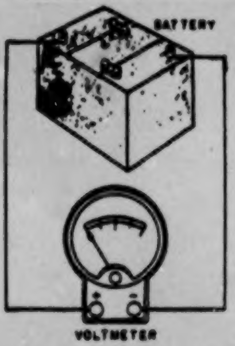


b. While one ampere may sound like a lot, in automotive electricity it is considered a rather small amount of current. Some lights may require about one ampere while a part like the starter motor may require 100 amperes or more.

**10. VOLTAGE.** As we said before, electron flow or current is caused by a difference in electron balance. In other words, when one end of a conductor has a positive charge and the other end has a negative charge, electrons will move to the positive end. The greater the difference in the amount of electrons at opposite ends of a wire, the greater the pressure will be that is pushing the electrons through the wire. This pressure is commonly called potential difference or VOLTAGE.

a. Voltage and its effect on electric current in a wire can be compared to pressure and its effect on water flowing in a pipe. When pressure is increased on water in a pipe, a greater volume of water will flow in a given period. If the voltage of an electrical circuit is increased, a greater number of electrons will move or a larger current flow will occur.

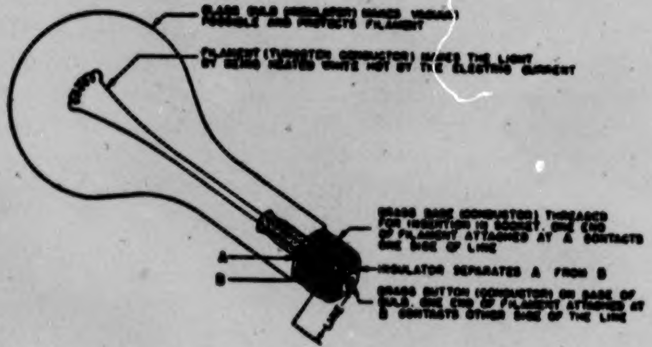
b. Voltage is measured with a VOLTMETER which will be covered in detail in later lessons. Military-type automotive vehicles that you will be working on have 24-volt electrical systems while most civilian-type vehicles have 12-volt systems.



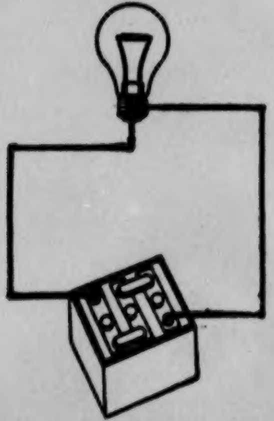
**11. RESISTANCE.** When the voltage forces current to flow in a wire the electrons meet RESISTANCE. The resistance is caused by the friction of the electrons bumping into the atoms. If we rub our fingertips across a table the friction causes heat. As you move your fingertips faster, the heat becomes greater. Likewise, electrons flowing through a wire cause heat. If the voltage is increased, current flow and the amount of heat is also increased. If the current flow is increased enough, the wire will become hot enough to literally burn up.

a. The heating action of current flow is one of the great uses of electricity. For an example let's take a look at the light bulb.

(1) The bulb contains a filament made of a material that has a lot of resistance to current flow and is able to withstand extreme heat. The filament ends are connected to two contacts at the base of the bulb. Usually the metal part of the base serves as one contact. The filament is then enclosed in glass and most of the air removed from the area surrounding the filament. If air gets to the filament, it will burn up easily.

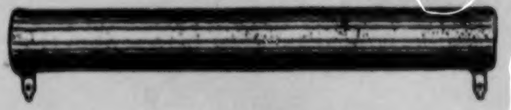

GLASS BULB (INSULATOR) MAKES VACUUM POSSIBLE AND PROTECTS FILAMENT
FILAMENT (TUNGSTEN CONDUCTOR) MAKES THE LIGHT BY BEING HEATED WHITE HOT BY THE ELECTRIC CURRENT
BRASS BASE (CONDUCTOR) THREADED FOR INSERTION IN SOCKET. ONE END OF FILAMENT ATTACHED AT A CONTACTS ONE SIDE OF LINE
A
B
INSULATOR SEPARATES A FROM B
BRASS BUTTON (CONDUCTOR) ON BASE OF BULB. ONE END OF FILAMENT ATTACHED AT B CONTACTS OTHER SIDE OF THE LINE
LINE

**(2) Voltage from a battery or other electrical source is applied to the two contacts at the base of the bulb. Current then flows through the filament causing it to get white hot which produces light. In order for the bulb to function properly the material in the filament, the size of the filament, and the amount of voltage supplied must be carefully balanced so just the correct amount of current will flow. If the current flow is too small, the filament will not get hot enough and the bulb will not glow brightly. If the current flow is too great, the filament will burn up.**

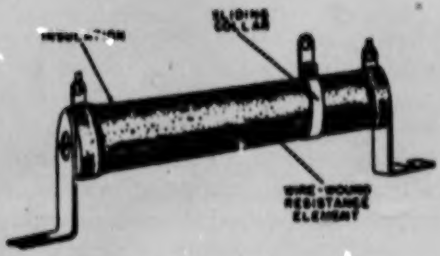


**b. Sometimes a special part called a RESISTOR is placed in the electrical circuit to reduce the current flow. The action of the resistor can be compared to the restricting action of a water valve or faucet. Opening the valve more will cause more water to flow because there will be less resistance to the flow of water. Likewise, reducing the resistance in an electrical circuit will cause more electrical current to flow.**

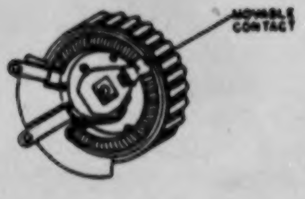
(1) Resistors are usually made from carbon or special wire. Some resistors are fixed; that is, they are made so you can't change the resistance as you can with the faucet in a water system. Resistors that you can adjust are called variable resistors or RHEOSTATS. A rheostat usually has a movable contact that you can move along the length of a resistor. By moving the contact you can change the effective length of the resistor. The greater the distance that the current moves to get through the resistor, the greater the resistance of the rheostat.



Fixed Resistor



Variable Resistor

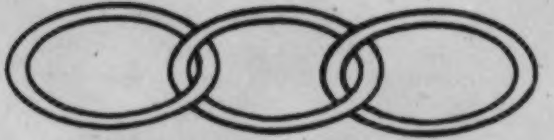


Rheostat

(2) The amount of resistance that a resistor or any other conductor offers to current flow is measured in OHMS. A material has one ohm of resistance when one volt (pressure) will force one ampere of current to flow through it. Resistance is measured with an OHMMETER which will be covered in a later lesson.

## 12. RELATIONSHIP OF QUANTITIES IN AN ELECTRICAL CIRCUIT.

There is a definite relationship between voltage, resistance, and amperes that must be considered when maintaining automotive electrical systems. From the example of the light bulb you can see that whether or not the bulb works as it should depends on the amount of current that is flowing through the circuit. From our study up to now you can also see that a change in either the amount of voltage or the amount of resistance will change the amount of current flowing in a circuit. Here are some rules about changes in voltage, resistance, and amperes that you should remember.

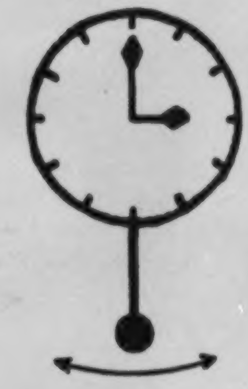


a. If the voltage in a circuit is made higher and the resistance remains the same, the amperes of current will also get higher. The reverse of this is also true — less voltage will cause less amperage.

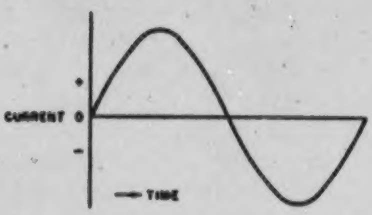
b. If more resistance is put in an electrical circuit the current is reduced, while less resistance allows more current to flow. Resistance can be changed by changing the length or diameter of a wire, by using a rheostat, or by using different sizes of fixed resistors.

13. ALTERNATING CURRENT. The electricity that comes to your home for operating the lights, refrigerators, etc, is called ALTERNATING CURRENT. Often alternating current is simply called AC. It was given this name because the electrons move through the wire first in one direction and then in the opposite direction. Since current flows from negative (surplus of electrons) to positive (shortage of electrons), the generating plant producing an alternating current must be periodically changing the electrical charge. In this manner, the electrons are caused to move back and forth in the circuit instead of in a constant stream moving in one direction only.

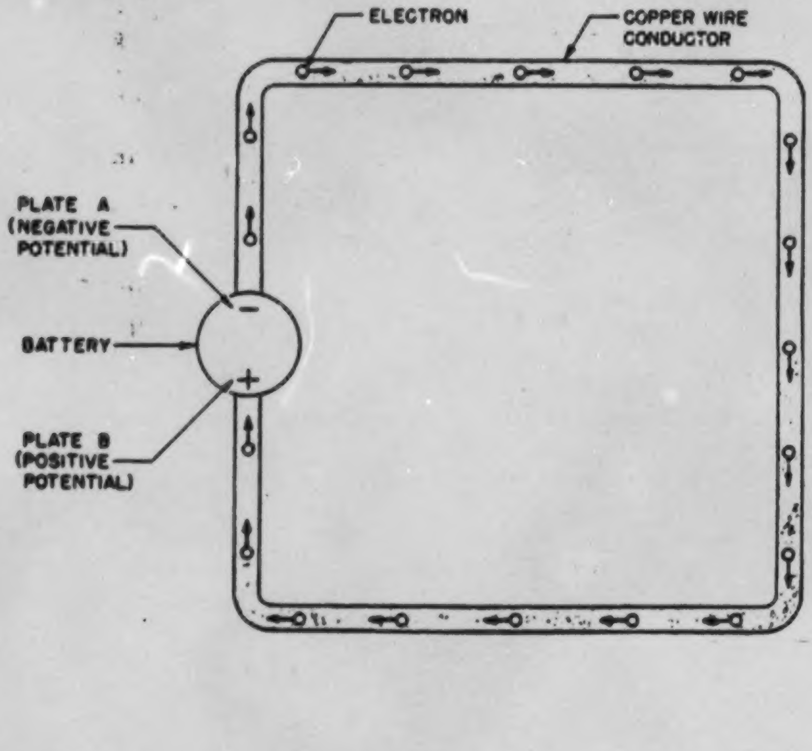
a. This can be illustrated if we compare AC to the pendulum of a clock. Current, like the pendulum, when starting from one extreme point to the right or left would start very slowly building up to its fastest speed at about one-half of its travel. Then its speed would begin to fall off until it comes to a complete stop for just an instant before repeating the same process in the opposite direction. Alternating current is defined as a current that is constantly building up or falling off and periodically changing direction.



b. When the electron flow returns to the same point it started from, just as the pendulum completes its swing to and fro, it completes one cycle. One cycle of alternating current is shown here in graph form that illustrates the current and time relationship. The number of cycles that occur each second is called the frequency of the current. The current supplied to your home, except in foreign nations and in some old neighborhoods, has a frequency of 60 cycles per second. Lately the term hertz is often used instead of cycles. So remember that both the term "60 hertz AC" or "60 cycle AC" means the same thing.

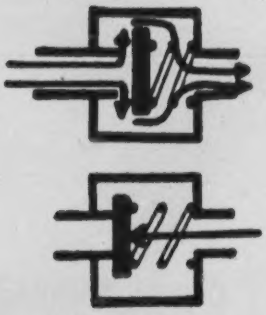


14. DIRECT CURRENT. Electric current that flows in one direction only is called DIRECT CURRENT. The term direct current is commonly shortened to DC. Batteries cannot reverse the electrical charge, as it must be done to produce AC, so they always supply DC (direct current). Since automotive vehicles use batteries, most electrical circuits that you will be working on use DC.

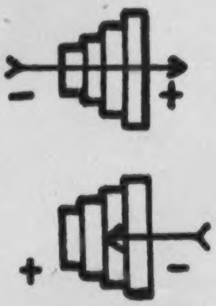


a. In automotive electricity we are sometimes faced with the problem of changing AC to DC. For instance, if the vehicle is equipped with an AC generator, the AC current cannot be used to charge the vehicle battery. In this case, the AC is changed to DC before it is mixed in the DC circuits.

b. Parts called RECTIFIERS or diodes are used to change AC to DC. The rectifier works like a one-way check valve in a water system. Water or current can flow through the check valve or rectifier in one direction, but flow is blocked in the opposite direction. Rectifiers are made from materials that have atoms constructed in such a manner that they allow electrons to move in one direction but not the other.



Check Valve



Rectifier

**Note.** - Complete exercises number 7 through 16 before continuing to section III.

7. A material that contains many free electrons is called

   a. a compound.
   b. a conductor.
   c. metal.

8. Which statement is true in reference to conductors?

   a. Copper is used more often than silver even though silver is a better conductor
   b. Aluminum is used over long spans because of its great strength
   c. The greater the conductor's length the better it conducts

9. What is the nature of an insulating material?

   a. It is very light
   b. It is very flexible
   c. It has few free electrons

10. Which material insulates the best?

    a. Oil
    b. Iron
    c. Gold

11. Which word best describes voltage?

    a. Volume
    b. Friction
    c. Pressure

12. When comparing electricity to water, amperes are comparable to

    a. rate of flow.
    b. pressure per square inch.
    c. resistance to flow.

13. The water faucet can best be compared to which component?

    a. Bulb
    b. Rheostat
    c. Fixed resistor

14. The term "ohm" refers to the amount of

    a. current moving past a given point in one second.
    b. potential needed to produce one ampere.
    c. friction encountered by an electric current.

15. The current in a circuit can be reduced by increasing the

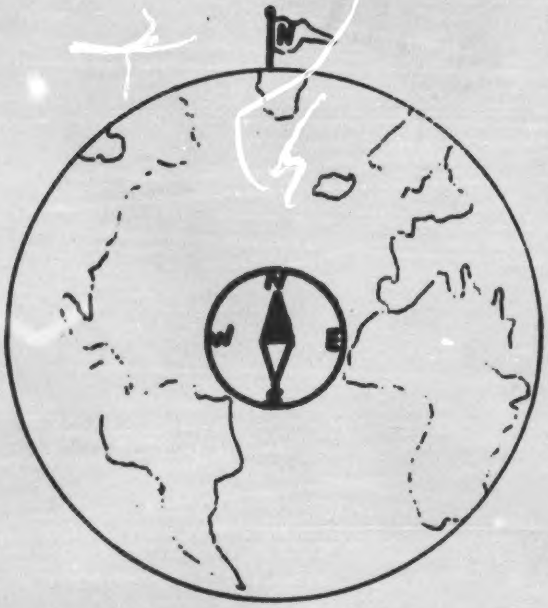
    a. applied voltage.
    b. diameter of the conductor.
    c. amount of resistance.

16. Which type of electric current is periodically changing in direction?

    a. AC
    b. DC
    c. Pulsating

## SECTION III. ELECTROSTATICS

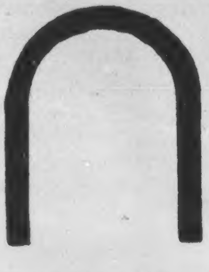
**15. MAGNETISM.** We know that it takes mechanical energy to crank an engine, yet it is done by supplying electrical energy to a starter motor from the vehicle battery. Also, we know that by using mechanical energy from the engine to drive the generator we are able to produce electricity. MAGNETISM is the connecting link between mechanical energy and electrical energy. In order to understand why it is we must first know some basic facts about magnetism.



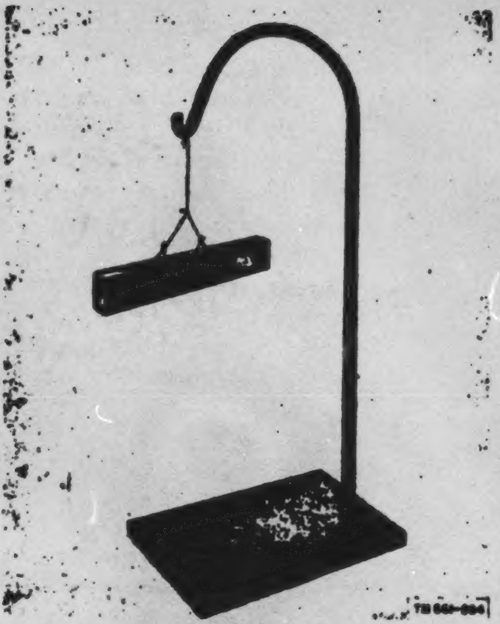
a. Magnetism is an invisible force that will attract iron and steel. It was first noticed in a particular type of stone called magnetite that is really a natural magnet. Magnetite was first used as a compass to tell directions when sailing on the ocean or traveling in unfamiliar country. This was possible because if a piece of magnetite is suspended so it is free to rotate it will turn so it points to the earth's magnetic north and south poles. One particular end always points to the north so it is called the north pole while the opposite end is called the south pole.

b. Although pieces of magnetite are natural magnets taken from the earth they have little value now. Better magnets can be made from iron and steel by artificial means. Magnets that are made from soft iron are called temporary magnets because they lose their magnetism quickly. Magnets made from steel are called permanent magnets because they stay magnetized for a long time. Permanent magnets that most of us are familiar with are the bar and horseshoe shaped kinds shown here. Let's discuss a few experiments with some permanent bar magnets to gain some knowledge of the invisible forces they possess.

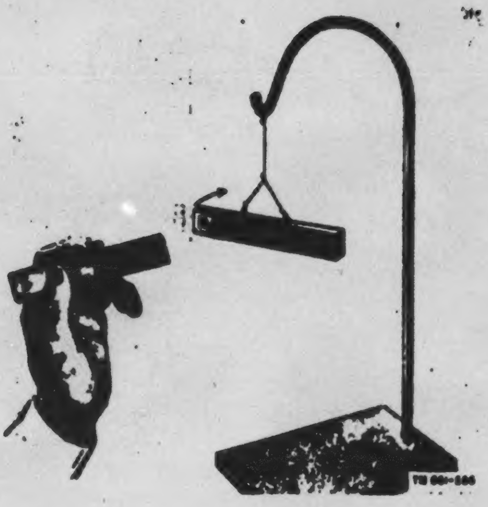
Bar Magnet


Horseshoe Magnet

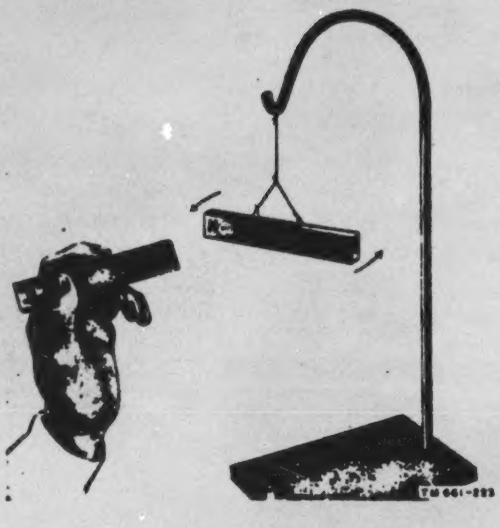
(1) If a bar magnet is suspended by a thread it will swing into a north - south direction with its ends pointing to the earth's magnetic poles. Like the magnetite, the end of the magnet toward the north is called the north pole and the end to the south the south pole.



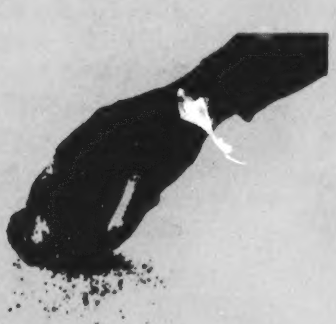
(2) If we obtain a second bar magnet and move its north pole toward the north pole of the suspended magnet we can see that the suspended magnet moves away from the second magnet. Likewise, if the south poles are moved close together the suspended magnet will move away. Therefore magnetic poles that are alike repel each other.



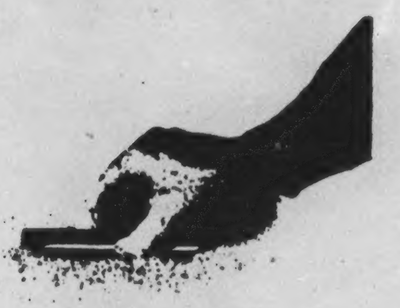
(3) Now let's move the south pole of the second bar magnet toward the north pole of the suspended magnet. Instead of moving away as it did before, the suspended magnet now moves toward the second magnet. In fact, if we allow the north and south poles of the magnets to come in contact they stick together and it takes considerable force to pull them apart. This last experiment then proves that unlike magnetic poles attract each other.



c. The surrounding space around a magnet that is affected by the magnet's invisible force is called a MAGNETIC FIELD. The magnetic field is often demonstrated by sprinkling some iron filings on a piece of paper that has been placed on a tabletop. A bar magnet is then dropped into the center of the paper. Of course a large number of the filings are immediately attracted to and moved about by the magnet.

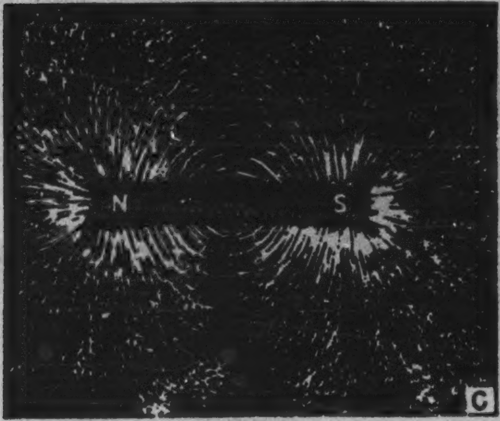


A

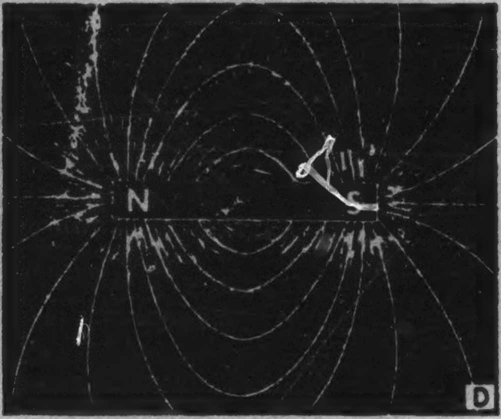


B

(1) If the tabletop is gently tapped, the filings move about and arrange themselves in a definite pattern of lines about the magnet. The pattern shape is determined by the forces of the magnetic field around the magnet. Notice that the lines are clear near the magnet and get less distinct farther away. This is because the magnetic field is strong near the magnet, but gets weaker as we move away.

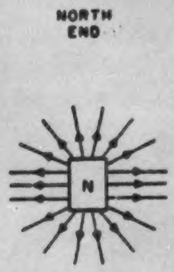


C

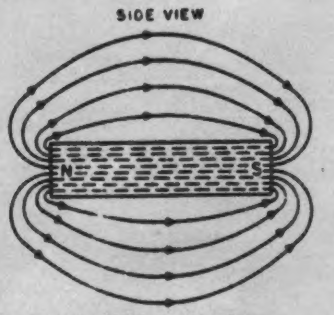


D

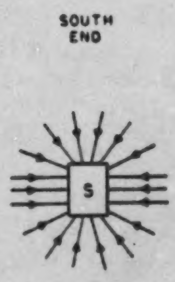
(2) The lines formed about the magnet are called LINES OF FORCE. Actually, the lines of force extend all the way around the magnet instead of just in a flat plane as shown by the filings on the paper. This is shown by the lines drawn at the end views of a bar magnet shown here. Note that arrowheads have been placed on the lines of force here to indicate direction of movement. Also note that the arrows indicate that the lines of force leave the north pole and enter the south pole.



FIELD OF FORCE
ABOUT NORTH POLE
LINES LEAVE POLE
IN ALL DIRECTIONS



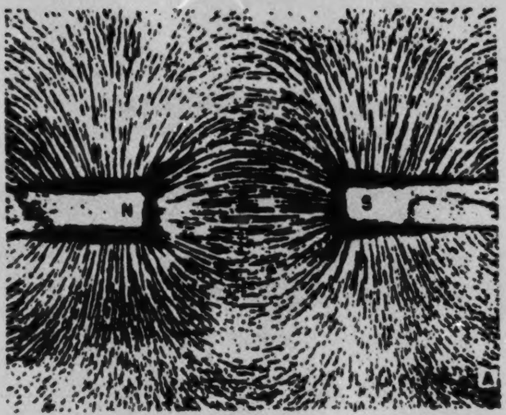
FIELD OF FORCE ABOUT A BAR MAGNET
LINES OF FORCE SHOWN IN ONE PLANE ONLY ACTUALLY, LINES EXTEND IN ALL DIRECTIONS AS SHOWN IN END VIEWS AND, THEORETICALLY, THROUGHOUT ALL SPACE



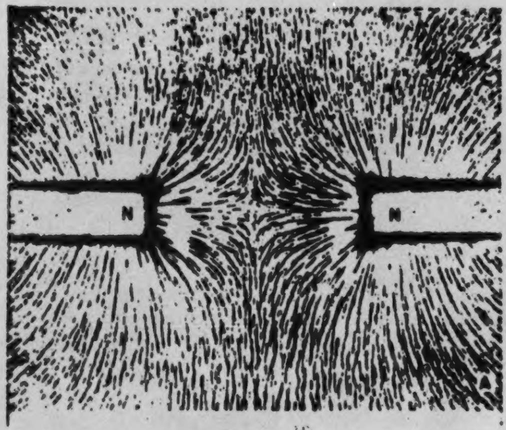
FIELD OF FORCE
ABOUT SOUTH POLE
LINES ENTER POLE
FROM ALL DIRECTIONS

TM 661-224

(3) It can be proved that the lines of force do have a direction of movement by using two magnets and iron filings. First place the magnets in iron filings so unlike poles are facing as shown. Notice that the lines of force between the unlike poles combine to increase the strength of the magnetic field between the two magnets. This indicates that the lines of force between unlike poles flow in the same direction.

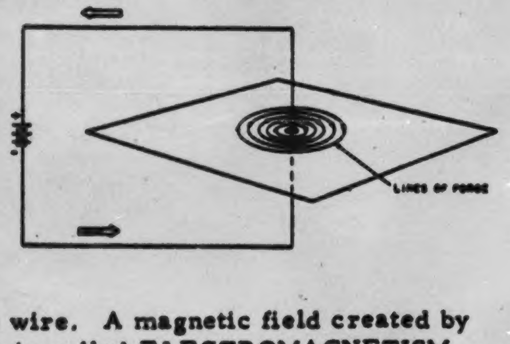


(4) Now position the two magnets so the like poles are facing. Notice that the iron filings in the magnetic field do not mix. Instead they turn away from each other indicating that they are moving in opposite directions, thus repelling each other.

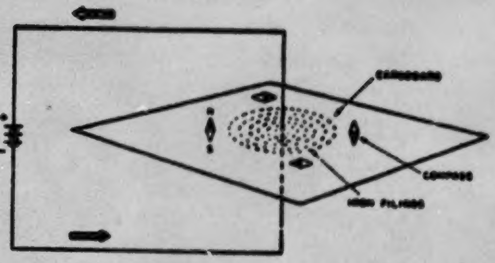


16. INDUCTION. By now you may be thinking, so what does magnetic force have to do with electricity? Well, let's give this matter more consideration and find out what the connection is and how it may be used.

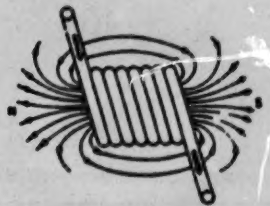
a. First, think about this experiment that is easily done. Pass a wire through a hole in the center of a piece of cardboard. With the cardboard level sprinkle iron filings on it around the wire. Now connect the wire to a battery so it conducts current and tap gently on the cardboard. The filings will then form circles around the wire. This proves that a magnetic field circles the wire. A magnetic field created by electricity, such as in this experiment, is called ELECTROMAGNETISM.



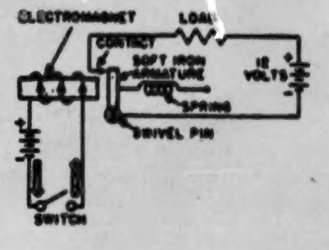
(1) We can carry the experiment out farther and prove that the lines of force about the wire have direction and that the direction is affected by the direction of current flow. Start by placing a compass at various points in the magnetic field around the wire. You will notice that the compass needle always alines with the lines of force with the north pole of the needle pointing in the direction of the magnetic field. Now reverse the wires on the battery terminals so the current flows in the opposite direction. The north pole of the compass needle will reverse the direction that it is pointing to prove that reversing the direction of current in the wire reverses the direction of the magnetic field.



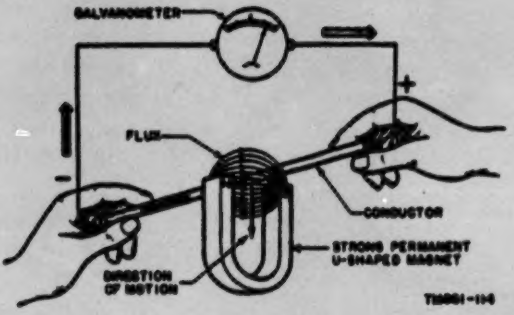
(2) An electromagnet is made stronger by increasing the amount of current flowing in the conductor or weaker by decreasing the current. It can be concentrated to make the magnetic field stronger in one area by winding the conductor into a coil. The more turns in the coil, the stronger the magnetic field in that area. Often an iron core is placed inside the coil to make the magnetic field even stronger. This is possible because the lines of force travel through iron easier than they do through air.



(3) The repelling and attracting forces of magnetic fields of electromagnets are used in electric motors and other devices to do mechanical jobs. In automotive vehicles these jobs range from cranking the engine to opening or closing small contact points in a relay switch.



b. Now, let's see how mechanical force can be used in creating an electric current. By obtaining a horseshoe magnet, a conductor such as a copper wire, and a sensitive current indicating meter such as a galvanometer this can be demonstrated.

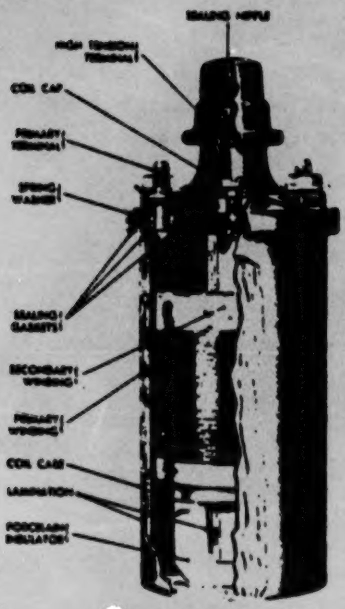


(1) Connect the meter to the conductor and then move the conductor downward between the poles of the magnet. When this is done the indicating needle on the meter will momentarily move away from zero indicating a surge of current flow. If the conductor is then held still in the magnetic field, the meter needle will not move from zero indicating that there is no current flowing in the conductor. This shows that the magnetic field causes free electrons to move, but only when the conductor is in motion moving across the lines of force.

(2) The amount of voltage and resulting current flow created (induced) in the conductor can be increased by several different means. The faster the conductor is moved across the lines of force the greater the voltage. Also increasing the strength of the magnetic field will increase voltage. Another method of increasing voltage is to wind the conductor into a coil so several turns of the coil can be passed through the magnetic field at one time.

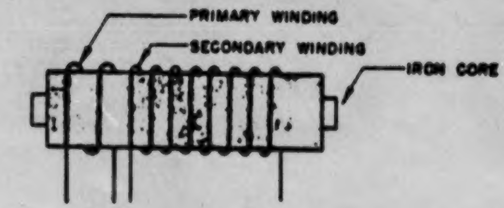
(3) As you can see in order to induce electricity in a conductor we must have a magnetic field and motion. In automotive generators mechanical energy from the engine is used to supply the motion. On some types of generators the conductor is moved through a stationary magnetic field, while on others the magnetic field is moved and the conductor is stationary. Just how this is done is explained in detail in the lesson on generators.

c. The induction principle is also used in the TRANSFORMER. A transformer is an electrical device that is used for stepping up or stepping down electrical voltage. The ignition coil of an automotive vehicle is actually a transformer that steps the 12- to 24-volt battery voltage up to the several thousand volts needed to ignite the fuel mixture. In the following paragraphs we will discuss the construction and operation of the transformer.


SEALING NIPPLE
HIGH TENSION TERMINAL
COIL CAP
PRIMARY TERMINAL
SPRING WASHER
SEALING GASKETS
SECONDARY WINDING
PRIMARY WINDING
COIL CASE
LAMINATION
PORCELAIN INSULATOR

Ignition Coil

(1) A simple transformer consists of two coils of wire and often contains an iron core. One coil is actually an electromagnet and is called the primary winding. The second coil is called the secondary winding.


PRIMARY WINDING
SECONDARY WINDING
IRON CORE

(2) If the primary winding is connected to a battery, current will flow through the winding causing a magnetic field to build up around the coil. As the field builds up, its lines of force move outward cutting across the coils of the secondary winding. The secondary winding will have a voltage induced in it as a result of the lines of force cutting across its coils. Now, if the ends of the secondary winding conductor were connected into a complete circuit, current would flow until the induced voltage dropped to zero.

(3) When the primary winding is disconnected from the battery the magnetic lines of force will collapse and disappear. As this happens the lines of force move rapidly inward toward the primary winding. Again the moving lines of force cut across the coils of the secondary winding inducing a voltage. This time the lines are moving in the opposite direction so the induced voltage will cause current to flow in the opposite direction.

**Note.** - Complete exercises number 17 through 20 before continuing to section IV.

17. Which item is used so electricity from an AC source can be used in circuits that contain batteries?

    a. Resistor
    b. Rectifier
    c. Transformer

18. Which magnets are positioned so they will be attracted to each other?

    a. [S N] [N S]
    b. [N S] [S N]
    c. [S N] [S N]

19. Which will NOT affect the strength of an electromagnet?

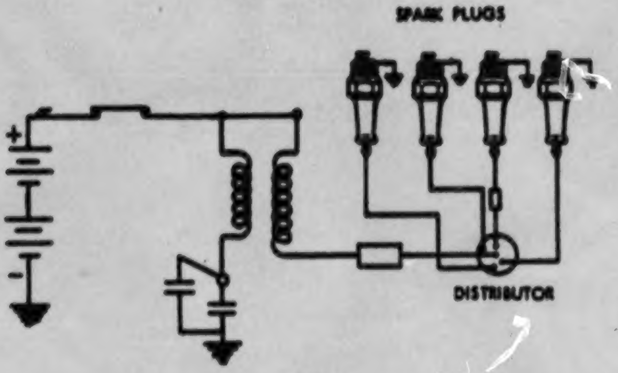
    a. The amount of current flowing
    b. The number of turns in the coil
    c. The direction of current flow

20. In a transformer, the motion needed for induction is provided by the

    a. iron coil core.
    b. magnetic field.
    c. secondary winding.

## SECTION IV. ELECTRICAL CIRCUITS

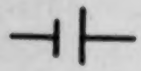
**17. SYMBOLS.** Automotive repair manuals do not use the same method to present all the information that is needed to repair the electrical systems. For instance, some of the information is presented through written words, but a lot is presented through drawings and the use of SYMBOLS. A symbol is a sign or figure that stands for something else. The use of symbols is especially useful in electricity since they can be used to show many things that are actually invisible.



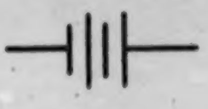
Ignition System

a. Before you will be able to read and obtain the needed information from the electrical drawings (commonly called schematic diagrams), you must first know the meaning of the symbols that are used. Let's take a look at some common symbols that are used in schematic diagrams of a automotive electrical circuits.

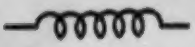
(1) One cell battery. The shortline represents the negative terminal, the longer line the positive terminal.



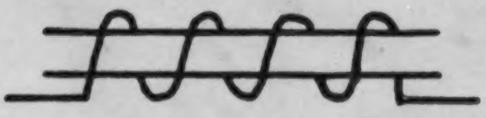
(2) Multicell battery.



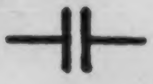
(3) Coil or electromagnet.



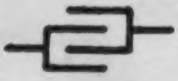
**(4) Coil or electromagnet with an iron core.**



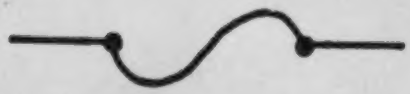
**(5) Condenser or capacitor. Either one of the two symbols may be used.**



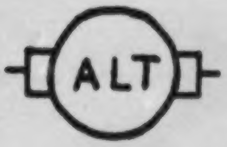
OR



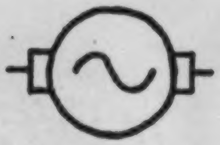
**(6) Fuse.**



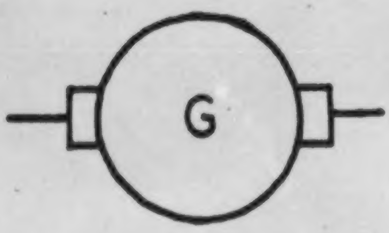
**(7) AC generator.**



OR



**(8) DC generator.**



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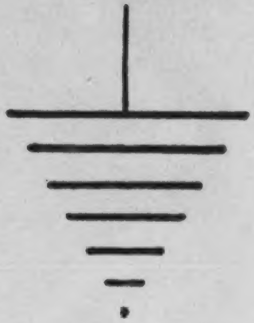
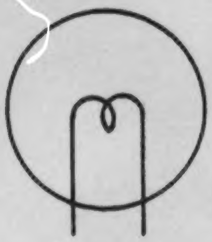
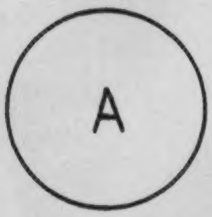
**(9) Ground.** In diagrams of automotive electrical circuits the ground symbol indicates a connection to the vehicle frame or body.



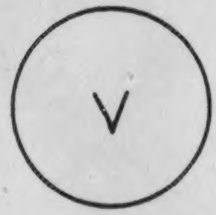
**(10) Lamp or bulb.**



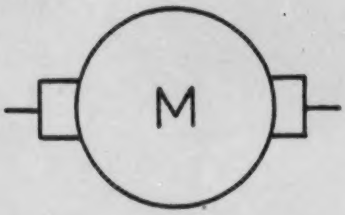
**(11) Ammeter.**



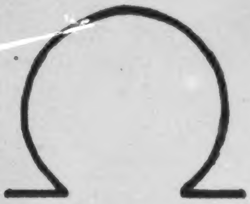
**(12) Voltmeter.**



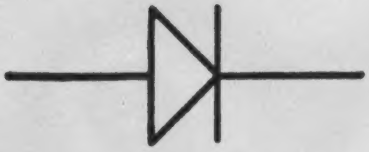
**(13) DC motor.**



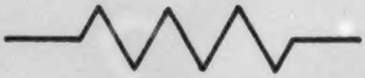
(14) Ohm. This symbol is usually accompanied by a number to indicate the amount of resistance. For example, if 5Ω is placed next to a resistor it means the resistor has 5 ohms resistance.



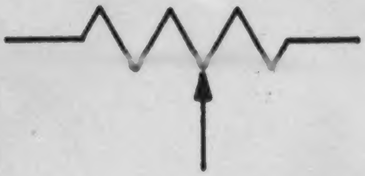
(15) Rectifier or diode. Current flow is blocked in the direction the arrowhead points in automotive electrical systems.



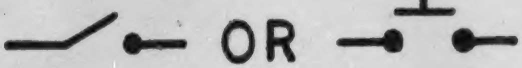
(16) Resistor.



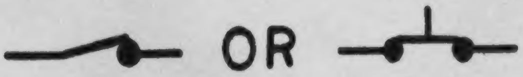
(17) Variable resistor or rheostat.



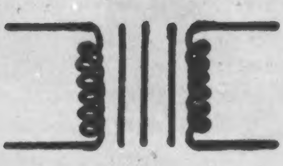
(18) Switch in the open (off) position.



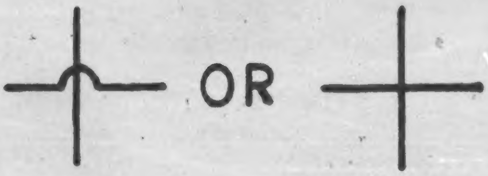
(19) Switch in the closed (on) position.



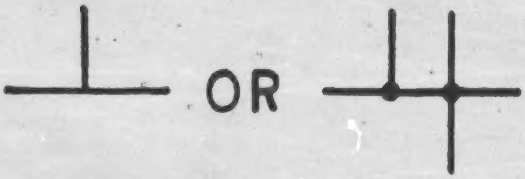
(20) Transformer with an iron core.



(21) Wires crossed, not connected.

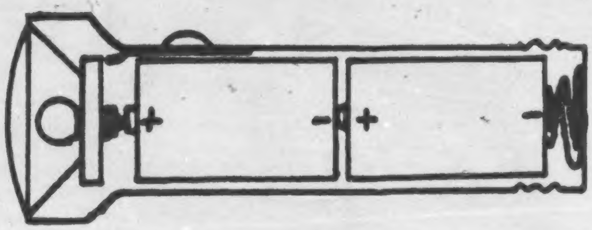


(22) Wires crossed, connected together.

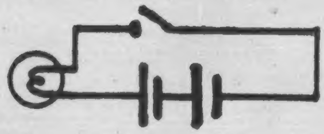


b. To see why and how symbols are used, let's consider the flashlight, an electrical device that we are all familiar with. In order to illustrate the flashlight we could take a photograph of it. This would show us the outside appearance of the light, but we could not use it to show the electrical paths formed by conductors like the bulb, switch, batteries, and spring inside the light.

(1) Of course, we could make a cutaway drawing like the one here. Without a doubt you could look at this kind of drawing and figure out the path that the electricity would follow to make the bulb glow. However, it takes considerable time and work just to make a drawing of a device as simple as the flashlight. Then it is none too easy for you to read. Imagine trying to do this for the entire electrical system of a wheeled vehicle.



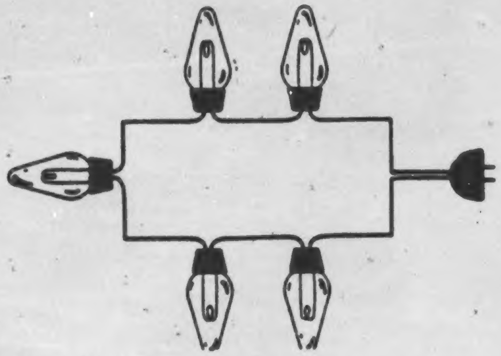
(2) Here the electrical circuit of the flashlight is shown by using symbols to form a schematic diagram. At a glance you can pick out the electrical path between the battery terminals. Also you can see that the current flow can be started or stopped by closing or opening a switch.



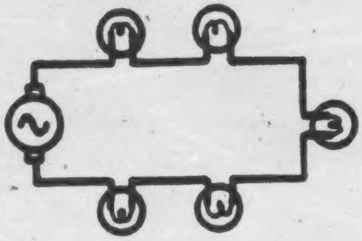
As you can see, this diagram is also very simple and easy to draw. Of course the schematic diagram does not show any detailed appearance of the parts, so it would only be used to illustrate the electrical circuit.

18. TYPES OF CIRCUITS. Electrical circuits can be laid out in series, parallel, or series- parallel. In order to troubleshoot an electrical circuit you must be able to identify the way it's laid out and understand how current flows in the circuit.

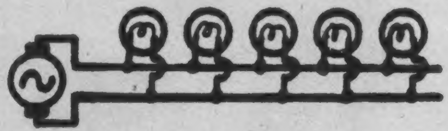
a. First, let's take a look at the SERIES CIRCUIT. A good example of this circuit is a string of series-connected Christmas tree lights. Can you recall a time when all the bulbs on one light set quit working because one bulb burned out? This is what happens when a series circuit is used.



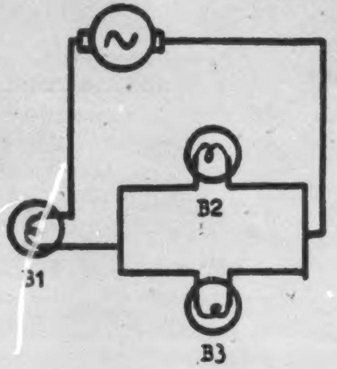
(1) The reason for all the lights going out can be easily explained with the schematic diagram of the light set. Notice that there is only one wire connected between each bulb. By following the electrical path provided, the current must flow from the power source to the first bulb, through the bulb filament, to the next bulb, through its filament, etc, in order to get back to the power source.



(2) If the electrical path is broken at any point, no current will flow and all the lights will go out. This happens when the filament in any one of the bulbs burns out or a wire breaks. Actually, a break in the circuit has the same effect as turning a switch off. To sum this up we can say that in the series circuit a number of items are connected together in such a manner so the current only has one path to follow.



b. In the PARALLEL CIRCUIT there is more than one path for the current to follow. This is the kind of circuit used when bulbs in a string of Christmas tree lights are connected together by two wires. Notice that each bulb provides a separate path for the current flow. If one bulb burns out, it will not affect the others. The parallel circuit is the most commonly used circuit in automotive electricity.



c. Now for the SERIES-PARALLEL circuit which is really a combined series and parallel circuit. This is illustrated by the three bulb circuit here. All the current flowing in the circuit must go through bulb 1. There is only one path here so this is the series part of the circuit. But on the other side of bulb 1 the electrical path divides; here part of the current flows through bulb 2 and the remainder through bulb 3. Then the paths join again to form a single path to the power source. The divided paths through bulbs 2 and 3 are the parallel part of the circuit.

19. ELECTRICAL CIRCUIT DEFECTS. In addition to the terms just discussed circuits are described as being grounded, shorted, open, or as having a high-resistance connection. These terms refer to conditions that exist in a circuit and usually are used to describe a defect. Let's go into these terms in more detail so you will be able to grasp the full meaning of each.

a. A GROUNDED circuit exists when defective insulation allows a conductor, such as a wire, to touch the vehicle frame. This probably causes most of the electrical fires on automotive vehicles so we will discuss this further.

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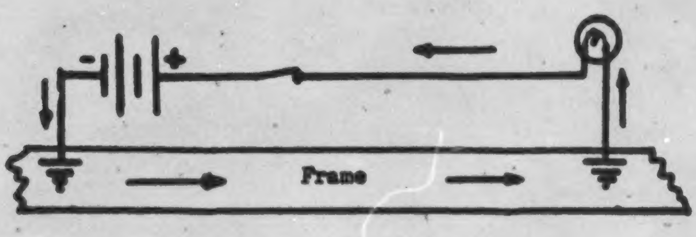
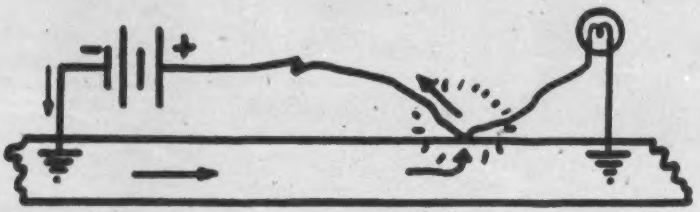
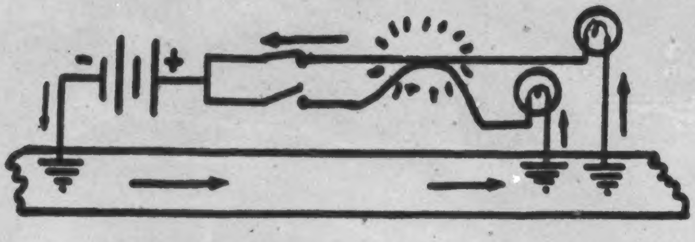
(1) In automotive circuits only one insulated wire to the battery is used. One battery terminal, usually the negative, is connected to the vehicle frame by a ground cable. The frame then serves as one conductor. Notice that when the switch is closed, current flows from the negative terminal of the battery, through the frame to the bulb, then through an insulated wire, light switch, and to the positive terminal of the battery.



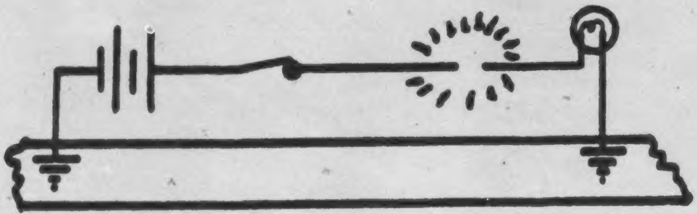
(2) Now, let's imagine that the insulation wears off exposing a bare spot on the wire between the light switch and the bulb. Let's further imagine that the exposed wire touches the frame as shown here. Battery current can now flow from the frame to the touching wire, through the switch, and back to the battery. Before, the high resistance of the bulb prevented a large amount of current from flowing. Now, with the wire grounded on the frame, current can bypass the bulb and we have a circuit with very little resistance. As a result, so much current will flow through the wire that it will get hot enough to melt and can set fire to any nearby flammable objects.



**b.** A SHORT CIRCUIT occurs when defective insulation allows two exposed wires to touch. This will let the current flow in the circuits for both wires even though the switch is closed in only one circuit. You can realize the results of this defect if you will imagine that a car has a short circuit between the wires to the tail and stop lights. When the light switch is turned on, battery current from the frame divides and flows through both lights and then joins to form one path at the short circuit. So both lights are burning even though the stoplight should not be.



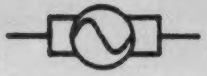
**c.** When an OPEN CIRCUIT exists no current will flow. For example, a light circuit is open when its switch is off or open, when a wire conductor is broken, or when the bulb filament is burned out. As you can see, an open circuit occurs in a circuit that is good by turning off the switch. The other conditions that we discussed here are caused by defects.

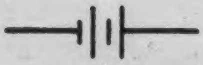


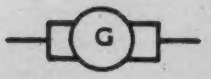
**d.** A HIGH-RESISTANCE CONNECTION is usually the result of corrosion at a battery post, wires loose at any terminal, or frayed wires. Frayed wires would have some but not all of the strands of wire broken. A high-resistance connection will reduce the amount of current flowing so the circuit doesn't work as it should. For instance, in a light circuit the bulb filament would not glow as bright as it should.

**Note.** - **Complete exercises number 21 through 25 before continuing to section V.**

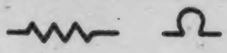
**21. Which symbol is used to represent the power source of a circuit using alternating current?**

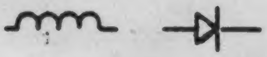
**a.** 

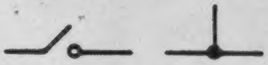
**b.** 

**c.** 

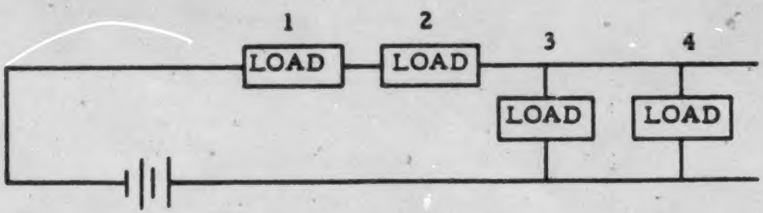
**22. Which group of symbols are related?**

**a.** 

**b.** 

**c.** 

**23. Which type of electrical circuit is shown in the following illustration?**



a. Series
b. Parallel
c. Series-parallel

24. Which circuit defect will prevent current flow?

a. Short
b. Open
c. Ground

25. If a vehicle's stoplight glows but is very dim, the cause is most likely

a. a high resistance connection.
b. an open circuit.
c. a short circuit.

## SECTION V. CONCLUSION

### 20. SUMMARY.

a. Electricity is caused by a flow of electrons through a conductor. An electric current will flow when there is a shortage of electrons at one end of a conductor and a surplus at the other. The electrons will move from the surplus (negative charge) to the shortage (positive charge).

b. Good conductors of electricity contain a large number of free electrons while insulators contain very few free electrons. The amount of current moving through a conductor is measured in amperes. The pressure causing the current flow is measured in volts. The amount of resistance a conductor offers to current flow is called its resistance and is measured in ohms.

c. Current that moves through a conductor in the same direction all the time is called direct current. Current that alternates, flowing first in one direction and then in the other, is called alternating current.

d. An invisible force called a magnetic field is present around a magnet. This force will move other magnets and metal objects without physical contact. Electricity will create magnets called electromagnets which react the same as natural magnets. In turn, a magnetic field combined with motion can be used to create electricity.

e. In order for electricity to flow it must have a completed circuit or path. Three kinds of circuits or paths are series, parallel, and series-parallel. Defective circuits may be described as being open, grounded, shorted, or having a high-resistance connection.

**21. PRACTICE TASK LIST DIRECTIONS.** Appendix A contains a list of tasks associated with the fundamentals of automotive electricity. They are representative of the tasks you will be required to perform as a wheeled vehicle mechanic. Perform all of the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

## APPENDIX A

## PRACTICE TASK LIST

**Practice Objective.** After practicing the following tasks you will be able to:

1. Draw schematic diagrams to illustrate common circuits.

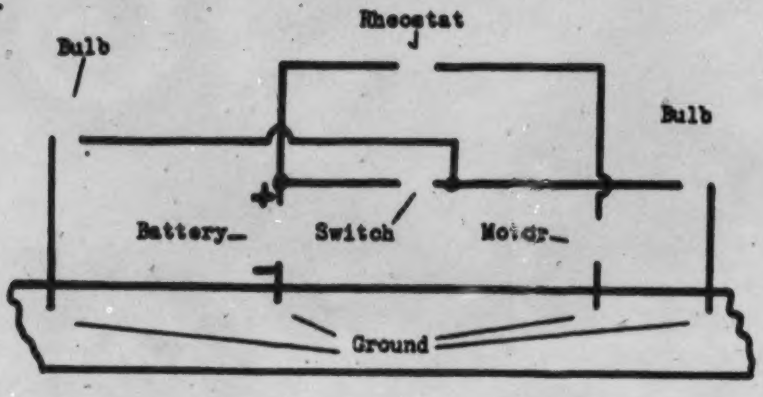
2. Use schematic diagrams in organizational level technical manuals.

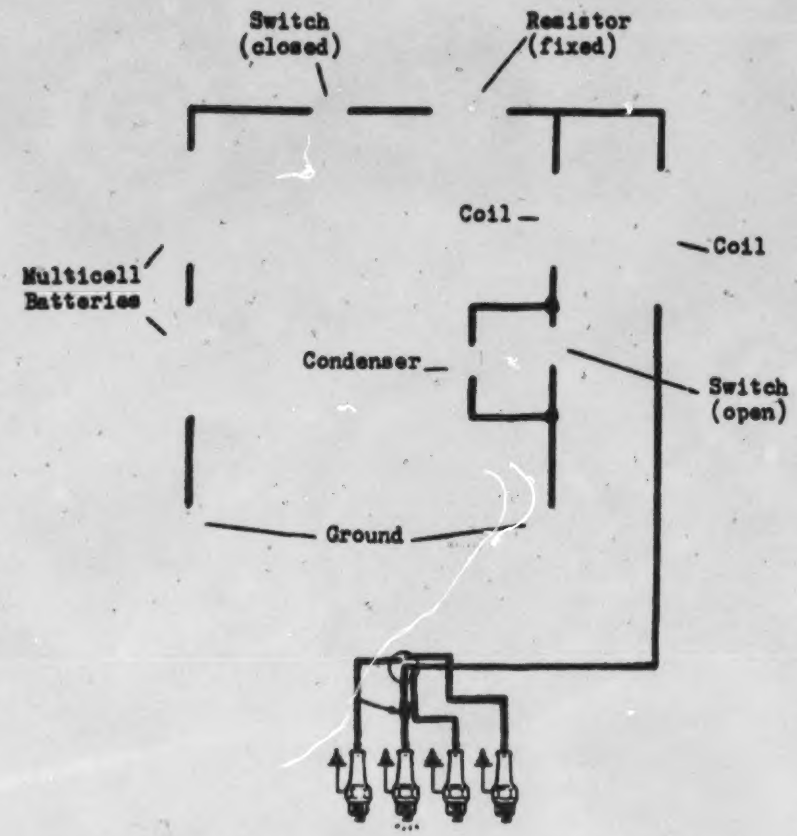
**Tasks.**

1. Draw the symbols in the spaces provided to complete the following diagrams. (See next page.)

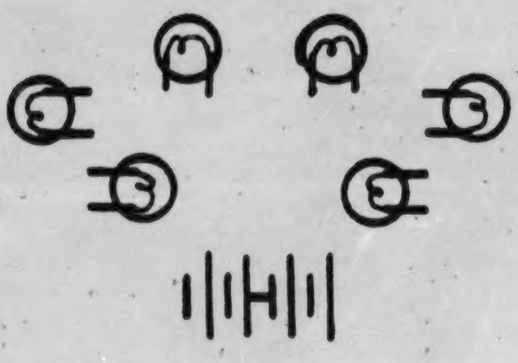
**Tasks.**

1. Draw the symbols in the spaces provided to complete the following diagrams.

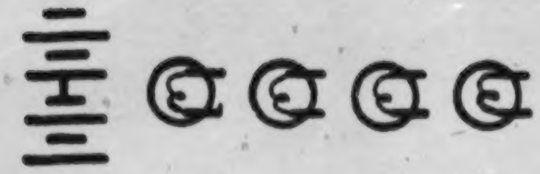

Rheostat
Bulb
Bulb
+
Battery
Switch
Motor
-
Ground


Switch (closed)
Resistor (fixed)
Coil
Coil
Multicell Batteries
Condenser
Switch (open)
Ground

2. Draw wires connecting the components to form a series circuit.



3. **Draw wires connecting the components to form a parallel circuit.**



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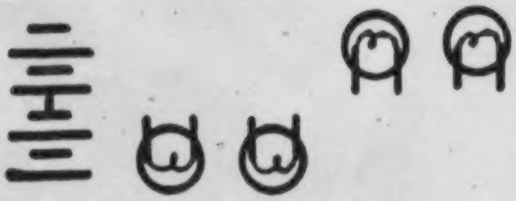
4. Draw wires connecting the components to form a series-parallel circuit.



5. Obtain a series -20 maintenance TM for each of the wheeled vehicles in your unit. Turn to the chapters that pertain to the electrical system and proceed as follows:

a. Locate schematic diagrams for the lighting, generating, starting, and ignition systems.

b. Identify the symbols used in the schematic diagrams. Notice that the appearance of the symbols representing the same components vary somewhat between different TM's.

c. Trace the current flow through several of the schematic diagrams.

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# APPENDIX B

## REFERENCES

| | | |
|---|---|---|
| TM 9-6140-200-12 | Operator and Organizational Maintenance Manual for Lead-Acid Storage Batteries | Sep 73 |
| TM 9-8000 | Principles of Automotive Vehicles | Jan 56 |
| TM 11-416 | Storage Batteries | Sep 55 |
| TM 11-661 | Electrical Fundamentals (DC) | Jun 51 |
| TM 11-664 | Theory and Use of Electronic Test Equipment | Feb 52 |
| TM 11-681 | Electrical Fundamentals (AC) | Dec 51 |

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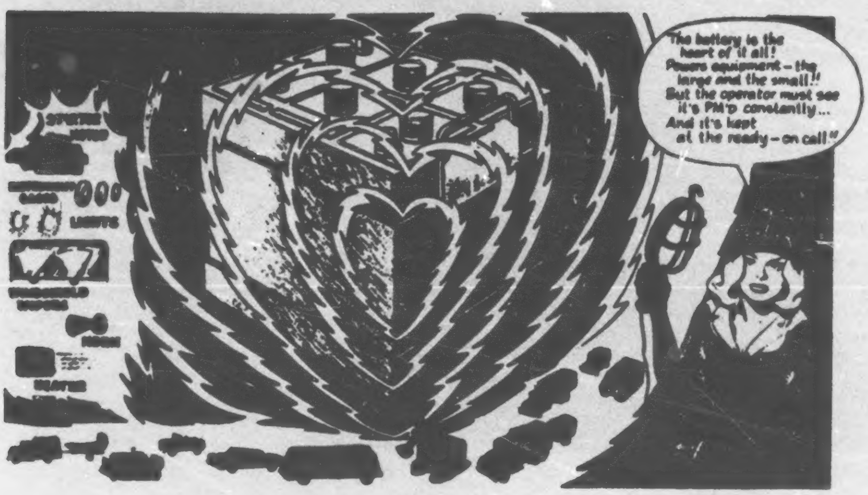
## ENLISTED MOS
## CORRESPONDENCE/OJT COURSE

# ORDNANCE SUBCOURSE 63B203


"The battery is the heart of it all! Powers equipment – the large and the small!! But the operator must see it's PM'd constantly... And it's kept at the ready – on call!"
LIGHTS

## LESSON 2
## AUTOMOTIVE BATTERIES

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

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# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

| | |
|---|---|
| Ordnance Subcourse 63B203. . . | Wheeled Vehicle Electrical Systems |
| Lesson 2 . . . . . . . . . . . . | Automotive Batteries |
| Credit Hours . . . . . . . . . . | Two |
| Lesson Objective . . . . . . . . | After studying this lesson you will be able to:<br>1. Describe the construction of batteries.<br>2. Explain the operation of batteries.<br>3. Describe the procedures used to check the specific gravity of battery electrolyte.<br>4. Explain the method used to rate batteries.<br>5. Identify methods of connecting batteries to increase the voltage and capacity. |

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6. Describe the procedures for performing preventive maintenance on batteries.

7. State the maintenance procedures required during adverse weather conditions.

8. Describe the procedures for slaving a vehicle that has discharged batteries.

9. State the procedures used to charge batteries.

10. State the procedures used to put new batteries in service.

| | |
|---|---|
| Study Assignment . . . . . . . . . . | Study the text thoroughly. This lesson will provide you with a knowledge of the fundamentals and maintenance of automotive batteries. |
| Materials Required . . . . . . . . | Exercise response list and answer sheet. |
| Suggestions . . . . . . . . . . . . . | Study all illustrations and printed material in each area until you understand it thoroughly before advancing to a new area. |

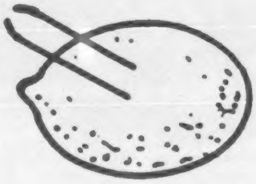
## STUDY TEXT

## SECTION I. FUNDAMENTALS OF AUTOMOTIVE BATTERIES

1. INTRODUCTION. In the last lesson you learned that electricity can be produced magnetically. Electricity is also produced chemically by means of a battery. Batteries used in automotive vehicles supply electricity for cranking the engine, igniting the fuel mixture in the cylinders, and operating most accessories. In fact, cars as they are designed now could not operate without batteries. In view of this it is easy to see that understanding the batteries and how to keep them in good condition are vital parts of good automotive maintenance. Present day cars would be quite helpless and of no use without the electricity furnished by a good battery that is properly connected. We, as mechanics, must know a great deal about batteries to keep them in good working order. Automotive batteries need daily attention from the operator plus some frequent maintenance that is performed by the operator and the mechanic, as well as special attention under certain conditions. To do your part you will need a good knowledge of batteries and the procedures involved in their maintenance. First let's take a look at batteries in general.

a. Simply stated a battery is nothing more than two unlike conductors immersed in a special solution known as electrolyte. You can even make a battery in a few minutes if you have a lemon, a paper clip, and a piece of uninsulated copper wire. Here is how it is done.

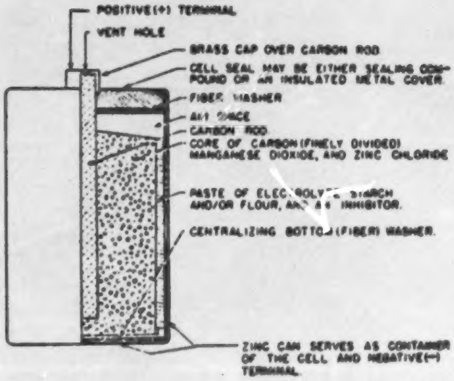
(1) Straighten out the paper clip and cut the wire so it is the same length as the paper clip. Stick both the clip and the wire deep into the lemon so they are close together but not touching. Now if you touch the free ends of the wire and paper clip to your tongue you will experience a slight tingle and a metallic taste.



(2) The tingle and metallic taste are due to electrons passing through the saliva on your tongue. The lemon juice is the electrolyte solution; the steel paper clip and the copper wire are the two unlike conductors. Action of acid in the juice combining with the conductors causes an excess of electrons to build up on one conductor. When you touched your tongue to the conductors you closed the circuit and electrons began to flow.

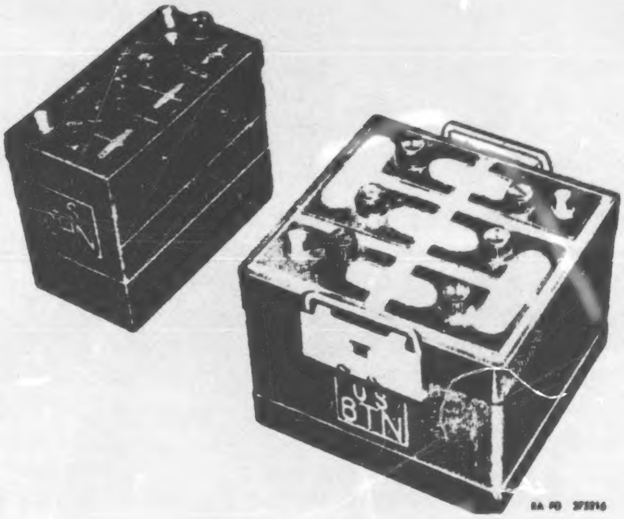
b. Almost everyone is familiar with the common flashlight battery which is often called a dry cell battery.

(1) The battery consists of a zinc cup-like container that is sealed at the top. A carbon rod is set in the middle of and insulated from the container. The rod extends out the top with its exposed tip covered by a metal cap. The cup is filled with a mixture of materials that make up a paste-like electrolyte. The carbon rod and the zinc case are the unlike conductors with the case containing the negative charge and the rod the positive.


POSITIVE(+) TERMINAL
VENT HOLE
BRASS CAP OVER CARBON ROD
CELL SEAL MAY BE EITHER SEALING COMPOUND OR AN INSULATED METAL COVER.
FIBER WASHER
AIR SPACE
CARBON ROD
CORE OF CARBON (FINELY DIVIDED) MANGANESE DIOXIDE, AND ZINC CHLORIDE
PASTE OF ELECTROLYTE, STARCH AND/OR FLOUR, AND AN INHIBITOR.
CENTRALIZING BOTTOM (FIBER) WASHER.
ZINC CAN SERVES AS CONTAINER OF THE CELL AND NEGATIVE(−) TERMINAL.

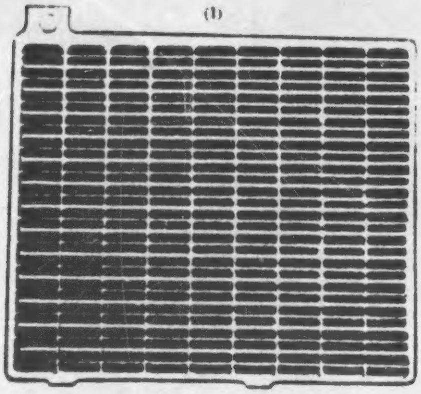
(2) A good flashlight battery has an electrical charge of 1-1/2 volts. As the battery is used, the voltage gets lower. Finally it reaches a point where it no longer furnishes enough electrical power to do the job right and must be replaced. The battery is then said to be discharged or run down.

2. CONSTRUCTION. Storage batteries used in automotive vehicles are the lead-acid type and are often called wet-cell batteries. They operate on the same principle as our lemon battery and the flashlight battery, using an electrolyte and two unlike conductors to store electrical energy in chemical form. In order to satisfy the high current and dependability requirements of automotive vehicles, the construction of the lead-acid storage battery is rather complex. The parts of the battery are described below in paragraphs a through h.

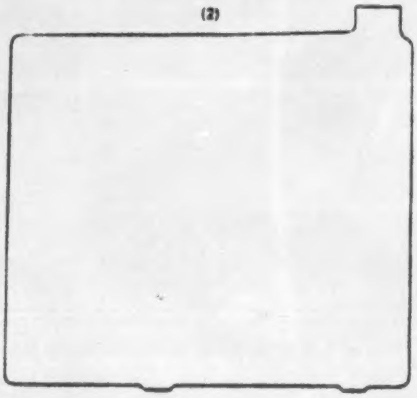


RA PD 372016

a. The conductors that are immersed in electrolyte are two kinds of PLATES known as positive and negative plates. Both the positive and negative plates have a grid framework made of stiff lead alloy for strength. The active material is applied to the grids in paste form and allowed to dry and harden like cement, then it is put through a special forming process. When finished, the active material of the positive plates is brown lead peroxide, the negative plates gray spongy lead.

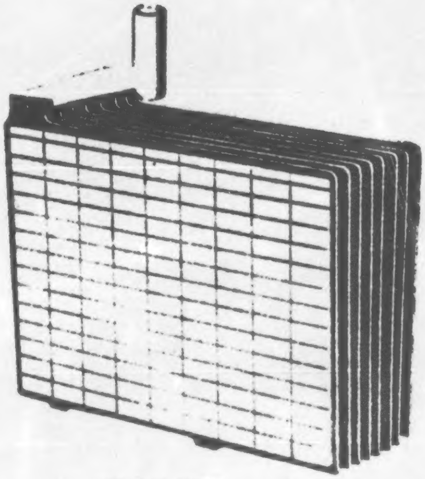


POSITIVE PLATE



NEGATIVE PLATE

b. Each plate has a lug on one top corner. Several plates are combined into positive and negative GROUPS by welding these lugs to a plate strap which is also made of lead. A negative group of plates has negative plates only and a positive group positive plates only. The plate strap on each group of plates contains a terminal post which forms an outside electrical connection.



NEGATIVE GROUP

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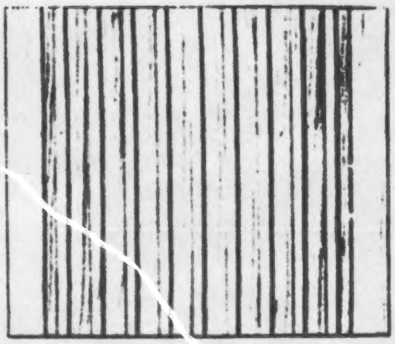
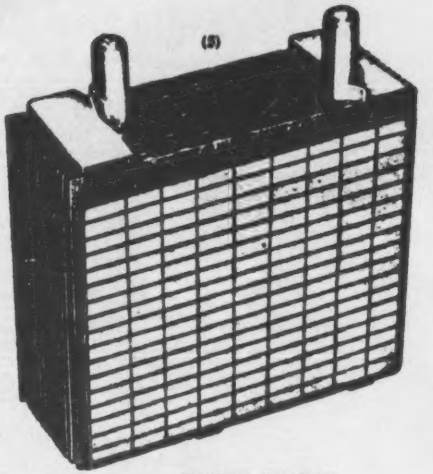
c. A positive and a negative plate group along with several insulators called separators are put together to form an ELEMENT. The thin separators are inserted between the positive and negative plates to prevent them from touching and short circuiting the battery internally. They are generally made of material such as wood, rubber, or glass and contain many small holes so the liquid electrolyte can pass through them.

(3)



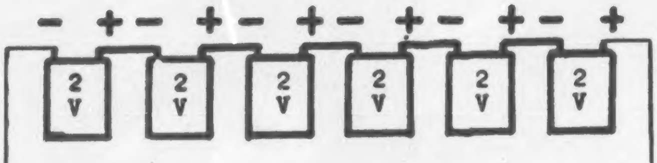
WOOD SEPARATOR

(5)

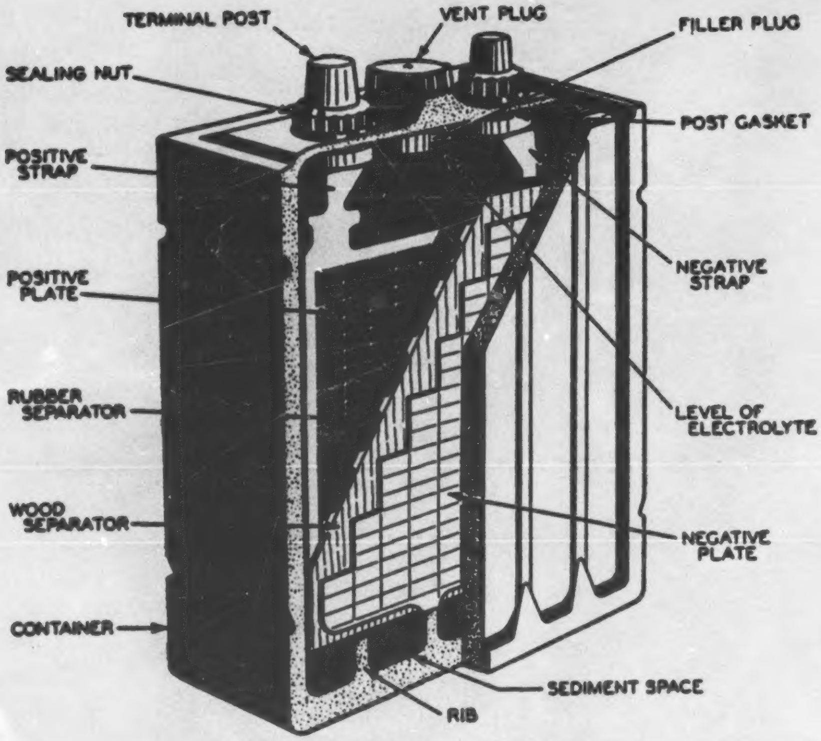


COMBINED ELEMENTS

d. When the assembled element, consisting of the positive and negative plate groups and separators, is immersed in electrolyte it becomes a CELL. The voltage of a charged cell as measured with an open circuit is about 2.1 volts, regardless of the size of the cell. For practical purposes we generally just say that the voltage of the cell is 2 volts. In order to obtain more than 2 volts from a battery several cells are used and connected in series (negative to positive). For example, a 6-volt battery will contain 3 cells and a 12-volt battery 6 cells. The cell terminals are connected by welding them to connector straps.

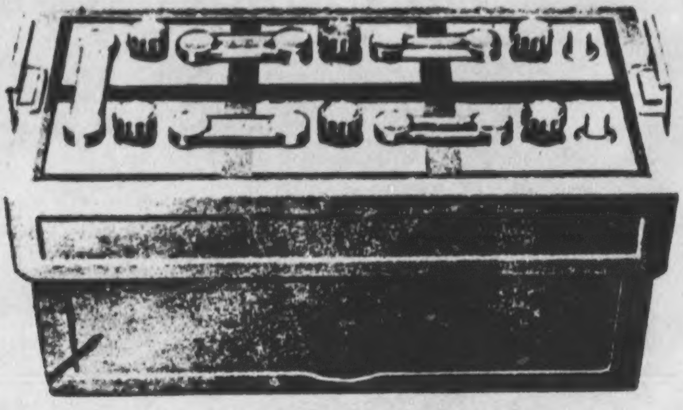


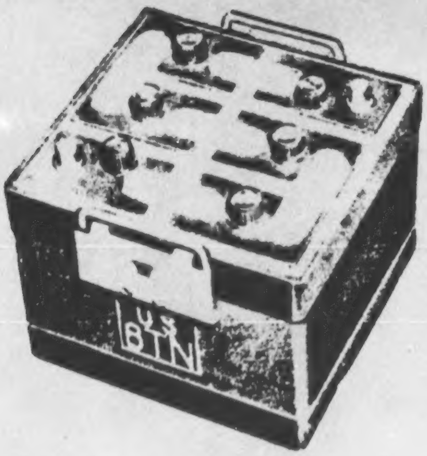
**e.** **All the cells of a battery are placed in a one piece CONTAINER or case that is divided into compartments. Each compartment is the container for one cell. The bottom of each cell compartment generally has raised ribs for the element to rest on. The area between the ribs serves as sediment space. During use, the active material on the plates gradually sheds and falls into the sediment space. The entire container is made of hard rubber or some other insulating material that is resistant to acid and mechanical shock.**


TERMINAL POST
VENT PLUG
FILLER PLUG
SEALING NUT
POST GASKET
POSITIVE STRAP
NEGATIVE STRAP
POSITIVE PLATE
RUBBER SEPARATOR
LEVEL OF ELECTROLYTE
WOOD SEPARATOR
NEGATIVE PLATE
CONTAINER
SEDIMENT SPACE
RIB

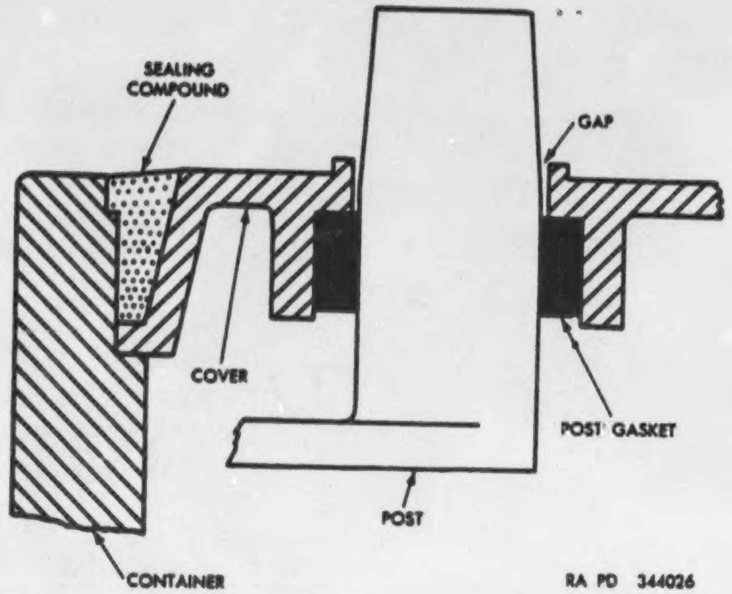
*Cutaway view of single cell.*

f. The top of each cell is fitted with a CELL COVER made from a material such as hard rubber like the container. Some batteries have cell covers made so the straps used to connect the cell terminals are exposed. On others, the connecting straps are covered and only two terminal posts are exposed. Regardless of the type of cover used each cell cover is fitted with a vent plug, which may be removed to inspect the cell or to add water.



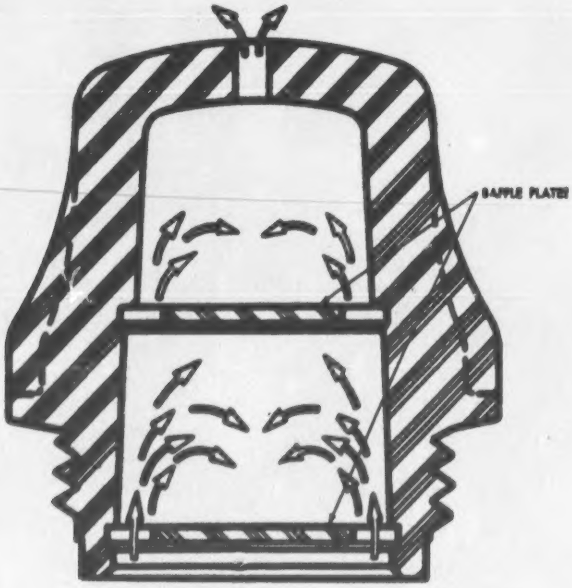


(1) To seal the battery after the cell cover is installed, the space between the edges of the cell covers and the container is filled with an acid-resistant battery sealing compound. Some form of seal is also used where the terminal post extends through the cover.

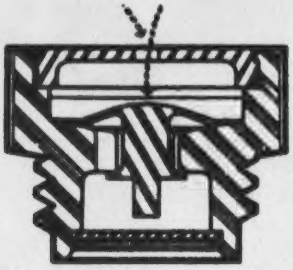

SEALING COMPOUND
GAP
COVER
POST GASKET
POST
CONTAINER

RA PD 344026

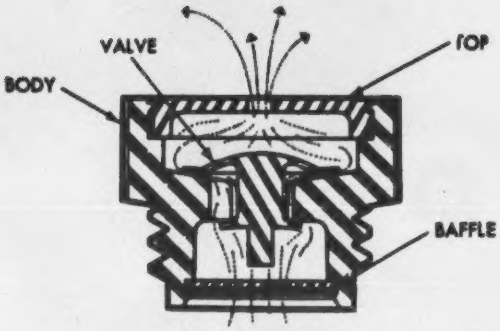
(2) The vent plug, which is also commonly called the filler plug, contains a small hole to permit the escape of gases formed in the cell. A series of baffles may be built into the plug so the gas must pass around them in leaving the cell. The baffles prevent electrolyte from splashing out through the venthole. Also, any mist from the electrolyte is collected here and returned to the cell.


BAFFLE PLATES

(3) Batteries that are designed for use in tactical vehicles are waterproof. On these batteries, the vent plugs will not allow water to enter the cells if the battery is immersed during fording operations, but will still permit gases to escape. This is done by a pressure vent valve in the vent plug. The valve closes to external water pressure and opens to release internal gas pressure.

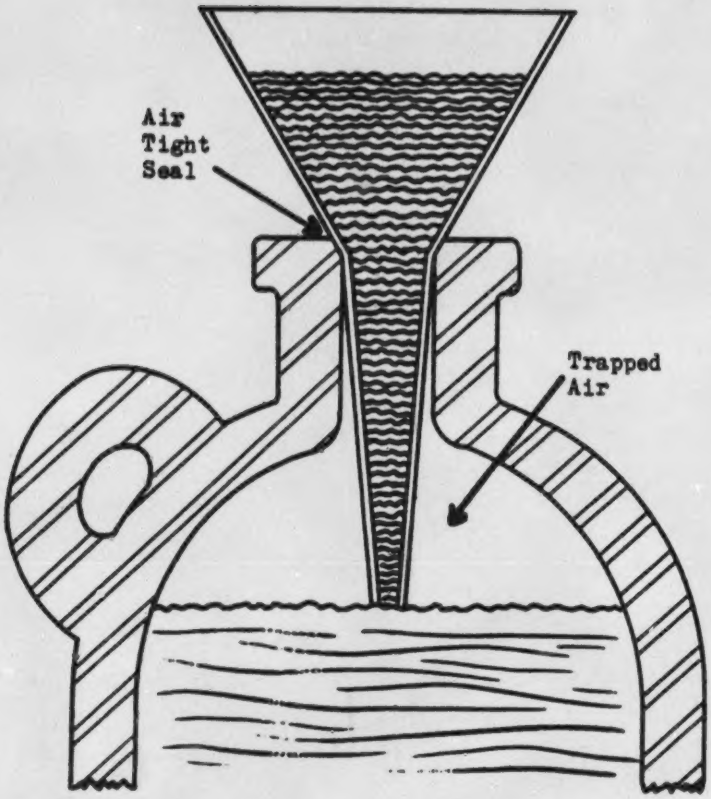


UNDER WATER PRESSURE
VALVE CLOSED



INTERNAL PRESSURE
VALVE OPEN

(4) To prevent overfilling the battery when adding water, many batteries have liquid level controls built into the filler openings of the cell covers. A level control device consists of a filler tube extending from the filler opening into the battery to the proper liquid level. Water can be added to a cell only to the bottom of the tube, then it rises inside the tube and not the cell. The principle of operation is illustrated here. When filling the jug the water level in the jug can rise no higher than the bottom tip of the funnel, since there is no way for the air to escape.


Air
Tight
Seal
Trapped
Air

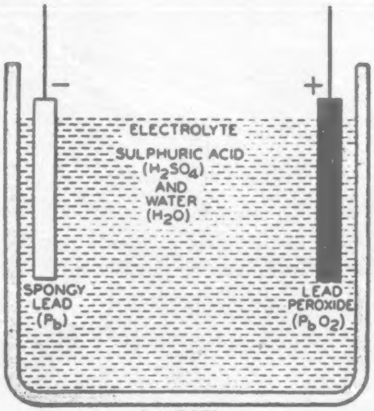
g. Electrical power is tapped from the battery through two TERMINAL POSTS. The terminals are tapered and the positive terminal is slightly larger than the negative terminal. The battery cable clamps are also made in two sizes, one to fit the positive terminal and the other for the negative to reduce the chances of connecting a battery in reverse.

GROUND
CABLE
TERMINAL
NUT

h. The cells of the battery are filled with a mixture of sulfuric acid and distilled water which is the ELECTROLYTE. Electrical energy is produced by the chemical action of the sulfuric acid on the plates. The electrolyte also serves as a carrier for the electric current inside the battery. The electrolyte of a fully charged battery contains about 38 percent sulfuric acid by weight or about 27 percent by volume.

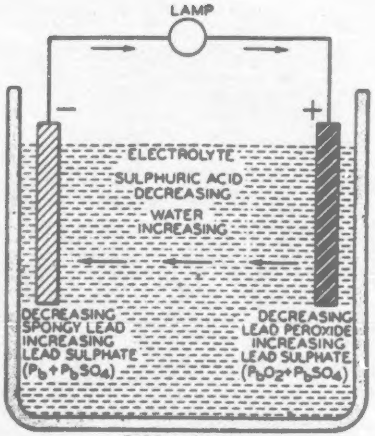
3. **OPERATION.** Now that you are familiar with the construction of the automotive battery, let's consider the chemical reaction that takes place in the battery.

a. A battery cell is said to be fully charged when the electrolyte is full strength, the active material of the negative plates consists entirely of spongy lead, and the active material of the positive plates consists entirely of lead peroxide.


−
+
ELECTROLYTE
SULPHURIC ACID
$(H_2SO_4)$
AND
WATER
$(H_2O)$
SPONGY LEAD $(P_b)$
LEAD PEROXIDE $(P_bO_2)$

CHARGED

b. When a load such as a lamp is connected to the battery, electrons flow through the lamp from the negative plates to the positive plates. At this time the battery is said to be discharging. Several chemical changes take place inside the battery during the discharge.

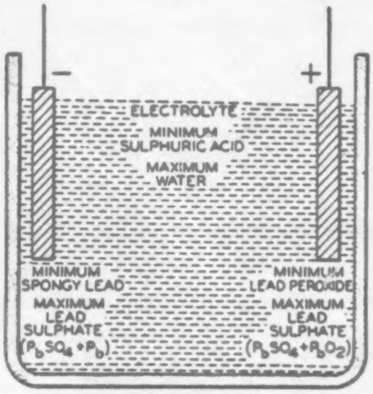

LAMP
−
+
ELECTROLYTE
SULPHURIC ACID DECREASING
WATER INCREASING
DECREASING SPONGY LEAD INCREASING LEAD SULPHATE $(P_b + P_bSO_4)$
DECREASING LEAD PEROXIDE INCREASING LEAD SULPHATE $(P_bO_2 + P_bSO_4)$

DISCHARGING

(1) As the current flows, atoms of the sulfuric acid leave the electrolyte and enter the battery plates. This decreases the amount of acid that is in the electrolyte making the mixture weaker.

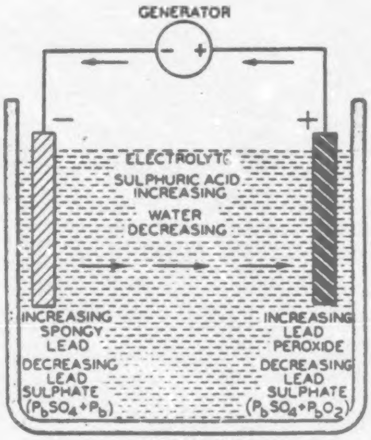
(2) As you recall, atoms from all elements are different, and the nature of all materials is determined by the atoms they contain. Therefore, the atoms of sulfuric acid mixing with the battery plates will change the nature of the plates. The spongy lead of the negative plates turns into lead sulphate; the lead peroxide of the positive plates also turns into lead sulphate.

c. If we leave the lamp connected to the battery, current flow continues and the electrolyte will get weaker and weaker until it is almost all water. At the same time, the negative and positive plates will be gradually turning into lead sulfate so that they are becoming like metals (lead sulfate). Finally the battery reaches a point where it will no longer supply enough voltage to cause the current flow and the lamp will stop glowing. The battery is then said to be discharged.


−
+
ELECTROLYTE
MINIMUM SULPHURIC ACID
MAXIMUM WATER
MINIMUM SPONGY LEAD
MAXIMUM LEAD SULPHATE
($P_bSO_4+P_b$)
MINIMUM LEAD PEROXIDE
MAXIMUM LEAD SULPHATE
($P_bSO_4+P_bO_2$)

DISCHARGED

d. The chemical reaction in the automotive battery that we just described can be reversed and a discharged battery returned to a charged state. This is done by supplying direct current from an external power source, such as a DC generator, and running it through the battery opposite the direction it travels when the battery is discharging. This causes the atoms from the acid to return to the electrolyte making the electrolyte stronger. As the acid atoms leave the battery plates they change back to their original nature — spongy lead and lead peroxide.

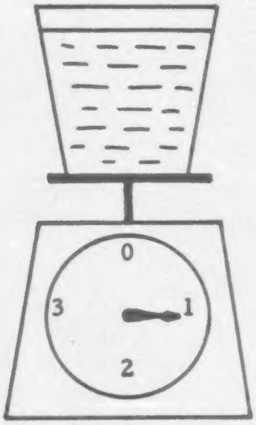

GENERATOR
− +
−
+
ELECTROLYTE
SULPHURIC ACID INCREASING
WATER DECREASING
INCREASING SPONGY LEAD
DECREASING LEAD SULPHATE
($P_bSO_4+P_b$)
INCREASING LEAD PEROXIDE
DECREASING LEAD SULPHATE
($P_bSO_4+P_bO_2$)

CHARGING

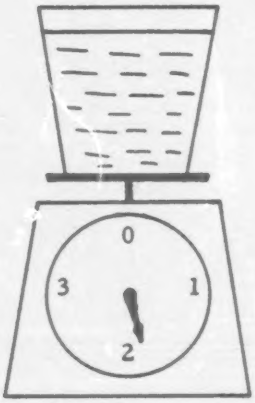
(1) As a battery is charged some of the water in the electrolyte is broken down and passed off in the form of gas. If charging is continued after the battery is fully charged the amount of gas given off is increased and the battery overheats. This is called overcharging and can damage the battery. The gas given off by a battery during the charging process is explosive and can be easily ignited by a spark.

(2) Repeated charging and discharging slowly wears out the battery. It causes the lead peroxide to fall off the positive plates into the sediment space in the bottom of the container. It is possible for the sediment to build up high enough to cause a short circuit between the negative and positive plates, but normally the cell will be worn out before the sediment reaches the short circuit stage.

4. SPECIFIC GRAVITY. The strength of the battery electrolyte is determined by comparing its weight to that of an equal volume of pure water. Pure water is said to have a specific gravity (weight) of 1.000. Let's suppose that we compare one gallon of water to one gallon of a second substance and find that the second substance weighs 2-1/2 times more than the water. The second substance is said to have a specific gravity of 2.500, or 2-1/2 times that of water. Pure sulfuric acid has a specific gravity of 1.835.



Water



Sulfuric Acid

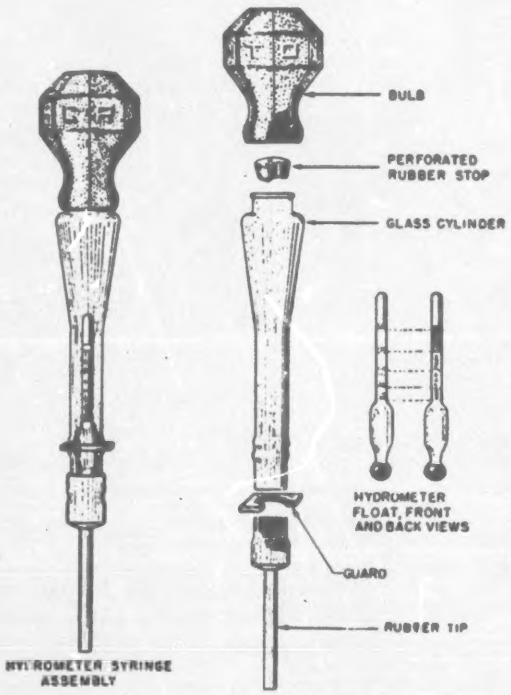
a. Since electrolyte is a mixture of sulfuric acid and water, the specific gravity of electrolyte will be more than the 1.000 of the water but less than 1.835 of the acid. The mixture that is generally placed in batteries has a specific gravity of 1.280 and by volume it contains 73 percent water and 27 percent sulfuric acid. In extreme weather conditions the mixture will vary, but this will be discussed later.

b. Often the specific gravity of the electrolyte is simply referred to as the gravity of the battery. Also, it is customary to omit the decimal point and refer to a specific gravity of 1.280 as "twelve eighty," 1.200 as "twelve hundred," etc. Variations of gravity in the third decimal place are referred to as points. For example, 1.284 is four points higher than 1.280.

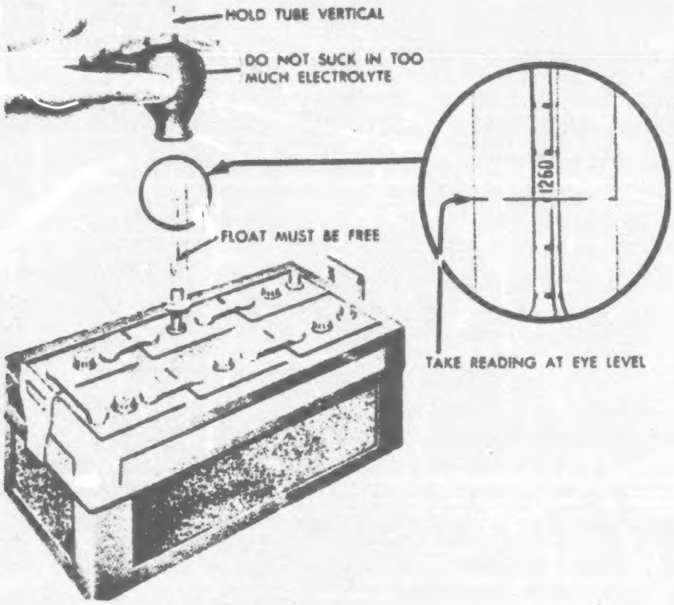
5. HYDROMETER. Since the amount of sulfuric acid in the electrolyte decreases as the battery discharges, the gravity of the battery also decreases as the battery's state of charge decreases. By using a tester, called a hydrometer, to measure the gravity of the electrolyte we can tell the battery's state of charge.

a. The hydrometer has a glass cylinder containing a glass float. A rubber inlet tip is fitted to the bottom of the cylinder and a rubber bulb at the top. A scale on the neck of the float has numbers ranging from 1.100 to 1.300. The scale may also be marked off in zones that are identified as full charge, half charge, and discharged, or good, fair, poor, and dead.

b. The amount that the hydrometer float sinks in a liquid indicates the specific gravity of the liquid. The float sinks low when the specific gravity is low and high when the specific gravity is high.


BULB
PERFORATED RUBBER STOP
GLASS CYLINDER
HYDROMETER FLOAT, FRONT AND BACK VIEWS
GUARD
RUBBER TIP
HYDROMETER SYRINGE ASSEMBLY

c. To test the gravity of a battery cell squeeze the hydrometer bulb and insert the inlet tip into the electrolyte of a battery cell. Hold the hydrometer in a vertical position and release the bulb to draw in just enough electrolyte so the float moves freely. To avoid wrong readings the float should not touch the sides or the top and bottom end of the cylinder. Hold the hydrometer so the surface of the liquid is level with your eyes, then read the mark on the scale at this level. Always put the electrolyte back into the cell to prevent weakening the mixture. Test all cells in the battery in the same manner.

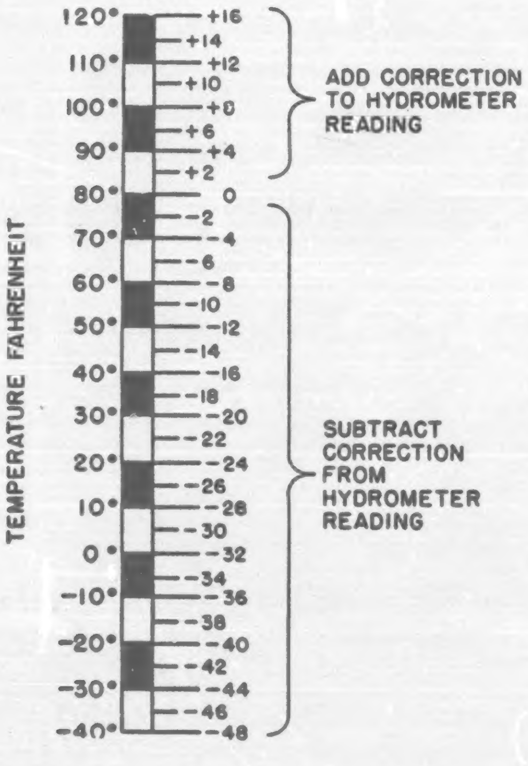

HOLD TUBE VERTICAL
DO NOT SUCK IN TOO MUCH ELECTROLYTE
1260
FLOAT MUST BE FREE
TAKE READING AT EYE LEVEL

d. The hydrometer should be kept clean by flushing it out once in a while with soapy water so the parts will not stick together. Inspect the hydrometer often for cracks. The float is hollow and if it develops a leak the hydrometer will no longer give the right readings.

e. The gravity of the battery is affected by temperature. When heated, the electrolyte expands so it occupies more space. When the temperature drops, the electrolyte contracts and takes up less space. In view of this, warm electrolyte will weigh less than the same volume of cool electrolyte, so warm electrolyte has a lower specific gravity than cold electrolyte.

(1) Electrolyte that has been mixed for normal use will test 1.280 at 80 degrees temperature. This is the temperature of the electrolyte and not the surrounding air. At ordinary temperatures it is not necessary to consider any variations when testing the gravity of a battery. However, any large variation above or below 80 degrees [illegible]ery important when deciding the true state of battery charge.

(2) In order to correct for temperature changes, test both the gravity and the temperature of the electrolyte. Some hydrometers have a built-in thermometer so you can do both at the same time. For each 10 degrees of temperature variation from 80 change the gravity reading 4 points. See the accompanying illustration. Add points to gravity readings when the electrolyte is above 80 degrees. Take points away when the temperature is below 80 degrees.


TEMPERATURE FAHRENHEIT
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
-20°
-30°
-40°
+16
+14
+12
+10
+8
+6
+4
+2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
ADD CORRECTION TO HYDROMETER READING
SUBTRACT CORRECTION FROM HYDROMETER READING

(3) The state of the battery charge for possible gravity readings is listed below.

| Specific gravity | | State of charge |
|---|---|---|
| 1.280 | | 100% |
| | Good | |
| 1.250 | | 75% |
| | Fair | |
| 1.220 | | 50% |
| | Poor | |
| 1.190 | | 25% |
| 1.160 | | Very little |
| | Dead | |
| 1.130 | | Discharged |

b. Other factors to consider when testing the gravity of a battery are the level of the electrolyte and how well the electrolyte is mixed.

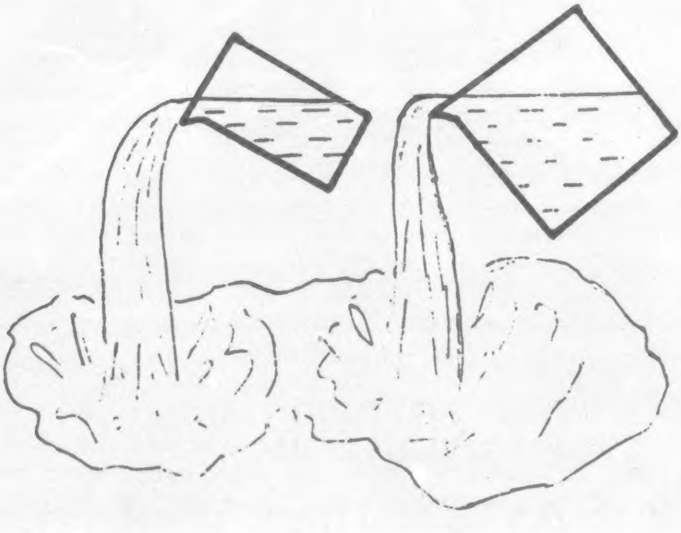
(1) The electrolyte should be at the correct level in the cell when it is tested. Water in the electrolyte evaporates, the acid does not. If the water has evaporated enough so the electrolyte level is low the mixture will be strong and the gravity reading will be high. On the other hand, if the battery has been overfilled with water the electrolyte will be weakened and the reading will be low.

(2) When water is added, it will tend to remain at the top of the cell so a hydrometer reading taken immediately after adding water would not be right. If water has to be added before taking a reading, the battery should be charged for 1 to 2 hours to mix the electrolyte before the hydrometer is used. This may be done by connecting the battery to a battery charger or by operating the vehicle.

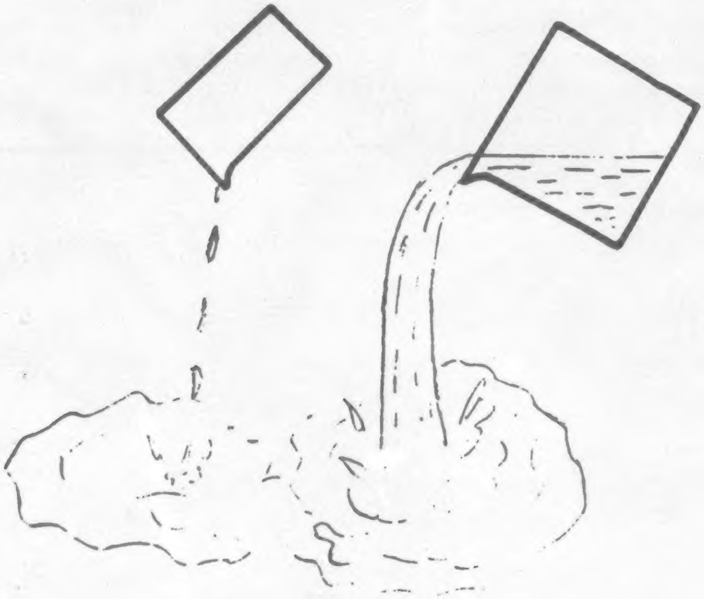
(3) Gravity readings will not tell the true state of the electrolyte if taken just after a battery has been discharged at a high rate. Such an instance would be just after the engine has been cranked for a long time. In this case, the acid has been used up next to the plates but the electrolyte near the top of the plates is still strong. The hydrometer will read a higher state of charge than that which actually exists. The electrolyte will mix so a true reading can be obtained if the battery is allowed to stand unused for several hours or if it is charged for 1 to 2 hours.

6. VOLTAGE AND CAPACITY. There is a distinct difference between the voltage and capacity of a battery.

a. This difference can be easily seen by picturing two cans of water, one small and the other large, placed on top of a building. If the water from both cans is poured over the side of the building the pressure or force it has when it hits the ground will depend on the distance it falls. The distance is the same regardless of which can the water comes from. This is comparable to battery voltage since voltage is electrical pressure. We have already stated that each cell of an automotive battery has slightly over 2 volts. This is true regardless of the size of the cell.



b. Now, let's imagine that one of the cans contains 1 gallon of water and the other can 5 gallons. You can see that if the water is poured from both cans at the same rate, water can be poured five times as long from the large can. From another viewpoint, if we empty both cans in the same length of time, the large can pours five times as much water for the same amount of time. This is comparable to battery capacity. More battery capacity is obtained by giving the electrolyte more plate surface to contact. This can be done by making the plates larger or by using a larger number of plates.



c. Even though battery voltage and capacity are different each one has a definite effect upon the other as well as on the circuit. Let's consider these effects for just a moment.

(1) We know that the battery must supply the correct amount of voltage to push just the right amount of current through the circuits. Too much voltage will cause too much current to flow which will burn out bulbs, etc. If battery voltage is too low, the current flow will not be enough and the circuits will not operate right.

(2) When a load is connected to the battery the current flow will cause the battery voltage to drop due to internal resistance in the battery cells. The amount of voltage drop under a load is affected by the following: the larger the capacity of the battery the less the voltage drops; as the battery's state of charge gets lower the voltage drops more; the greater the current flow the greater the voltage drop; as the battery wears out active material drops off the plates, which reduces the battery's capacity and causes a larger voltage drop under the load; as temperature drops the electrolyte gets thicker, which slows down its action and causes a larger voltage drop during cold weather.

7. BATTERY RATINGS. The current requirements of the electrical systems of two vehicles are often different even though they require the same amount of voltage. For instance, both the 1/4-ton and 5-ton trucks have 24-volt electrical systems, but the batteries used in the 1/4-ton truck will not supply enough current to satisfactorily crank the large engine of the 5-ton truck. We can tell which of two batteries has a larger capacity or current producing ability by their physical size, just as telling which of two cans will hold more water, but this is not an exact measurement.

a. The amount of water a can will hold may be measured in pints, quarts, or gallons. Battery capacity is measured in ampere-hours which is the number of amperes the battery will deliver multiplied by the number of hours the battery will deliver it. For example, suppose a battery will deliver 5 amperes for 20 hours, then 5 amperes multiplied by 20 hours equals 100 ampere-hours.

(1) If the ampere-hour rating is based on nothing more than the method described above the rating would change if the rate of discharge is changed. Suppose that we increase the load on the battery from 5 to 10 amperes. The battery would then produce the 10 amperes for a period less than 10 hours so its rating would figure to be less than 100 ampere-hours. As you can see, some form of standard procedures must be used to rate the ampere-hours before the ratings will mean the same in all tests.

(2) The capacity of automotive batteries is rated by standard procedures called the 20-hour rating. This rating gives the number of ampere-hours the battery will deliver if it is discharged at a uniform rate for 20 hours, at a temperature of 80 degrees, and with a battery voltage of 1.75 volts per cell at the end of the 20-hour period.

(3) Two sizes of batteries, type 2HN and 6TN, are commonly used in tactical wheeled vehicles. Both types are 12-volt batteries. The smaller 2HN battery is rated 45 ampere-hours, the larger 6TN battery is rated 100 ampere-hours.

b. Through use and age the capacity of a battery decreases. This is due to some of the active material dropping off the plates and the build up of a hard coating of sulfate on the plates. Because of this, testing the gravity of the battery with a hydrometer may not always reveal the true conditions of the battery. The electrolyte may be strong enough, but the battery capacity may be reduced to a point where the available current supply is too small. This condition can be detected by making a high-rate discharge test of the battery.

(1) Do not perform a high-rate discharge test when the specific gravity of the electrolyte is 1.225 or less, or if the variation of specific gravity between cells is more than 25 points. After charging, the battery should be allowed to set for several hours before making a high-rate discharge test.

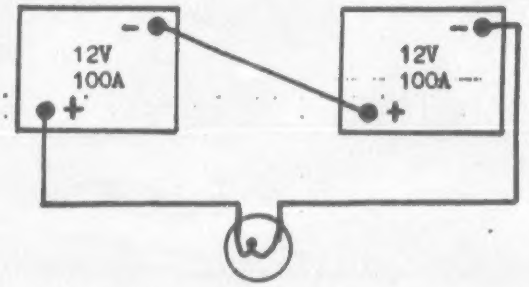
(2) High-rate discharge testers are available for testing batteries but the test instruments vary a great deal. Always perform a high-rate discharge test according to instructions that are with the test instrument. In use, the test instrument draws a high current from the battery and the battery voltage is read on a voltmeter during the discharge. The correct amount of voltage will vary depending on the test instrument used.

(3) If a high-rate discharge tester is not available, batteries can still be tested if they are installed in the vehicle. This is done by using an ordinary voltmeter to measure the battery voltage while cranking the engine. The starter motor serves as the high-current load. Refer to the series-20 TM for the vehicle that the test is being performed on for the exact procedures and correct voltage readings.

## 8. CONNECTING BATTERIES IN SERIES AND SERIES-PARALLEL.

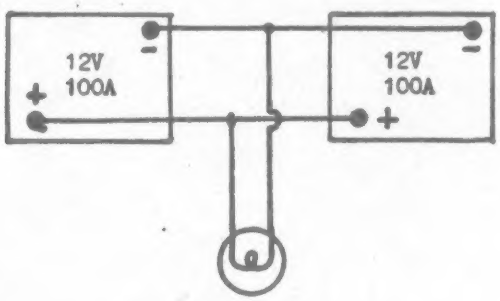
As you know, tactical vehicles have 24-volt electrical systems which is twice the voltage supplied by the 12-volt batteries used. In addition, some of the vehicles demand more current for cranking than the 100 ampere-hour battery can supply. In order to satisfy the increased voltage and current requirements more than one battery is used in each vehicle. In order to satisfy the specific requirements of different vehicles the batteries are connected in series or series-parallel.

a. In order to increase voltage the batteries are connected in series. Recall that in a series circuit the current has only one path to follow; therefore, the same current will flow through all batteries when they are connected in series. A series connection of two batteries is made by connecting the negative terminal post of one battery to the positive terminal post of another battery. Batteries connected in series should have the same ampere-hour rating. A voltage source equal to the sum of both batteries is then available at the two remaining terminal posts. The ampere-hour rating of batteries connected in series is the same as the smallest battery by itself. For instance, some trucks use two 6TN batteries which are rated at 12 volts and 100 ampere-hours each. The batteries are connected in series to furnish a power source of 24 volts and 100 ampere-hours.



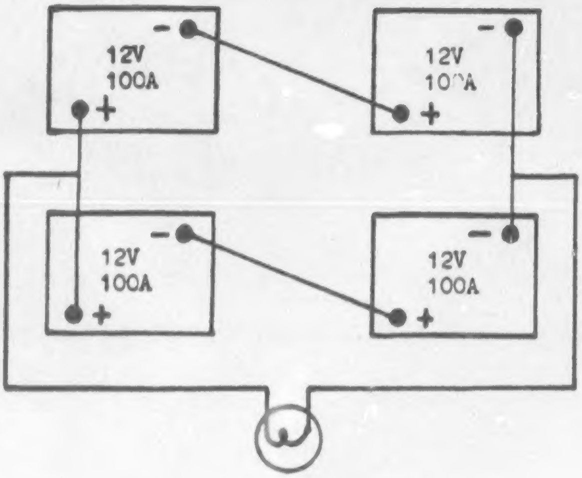
24 Volt 100 Ampere-hour Supply

b. In order to increase the ampere-hour rating the batteries are connected in parallel. In a parallel circuit the current has more than one path to follow. Batteries connected in parallel must have the same voltage rating. To connect two batteries in this manner, the positive terminal posts of both batteries are connected together and then the negative terminals of the batteries are connected. Each battery will now furnish half the current flowing in the load so their ampere-hour ratings will be added together, but the voltage will be the same as one battery alone. The parallel connection of batteries when used in tactical wheeled vehicles is combined with the series connection and called the series-parallel connection.



12 Volt 200 Ampere-hour Supply

c. Batteries are connected in series-parallel to increase both the voltage and the ampere-hour rating. To demonstrate how we make use of the series-parallel connection let's say that we have a vehicle that requires a 24-volt, 200-ampere-hour power source. We will use four 12-volt, 100-ampere-hour batteries. The batteries are first set apart into groups of two. In each group the batteries are connected in series so they will provide 24 volts and 100 ampere-hours per group. Then, the two groups are connected in parallel to increase the capacity rating to 200 ampere-hours.



24 Volt 200 Ampere-hour Supply

Note. - Complete exercises number 26 through 31 before continuing to section II.

26. The positive and negative plates in the lead-acid battery are made mechanically strong by the use of a

    a. separator.
    b. grid.
    c. paste.

27. What is the correct specific gravity of a battery that reads 1.280 at 100° F?

    a. 1.288
    b. 1.280
    c. 1.272

28. When a battery is being charged, its positive plates are changing from

    a. lead sulphate to lead peroxide.
    b. lead peroxide to lead sulphate.
    c. lead sulphate to spongy lead.

29. A battery that will deliver 6.5 amperes for 20 hours before the cell voltage drops to 1.75V is said to have an ampere-hour capacity of

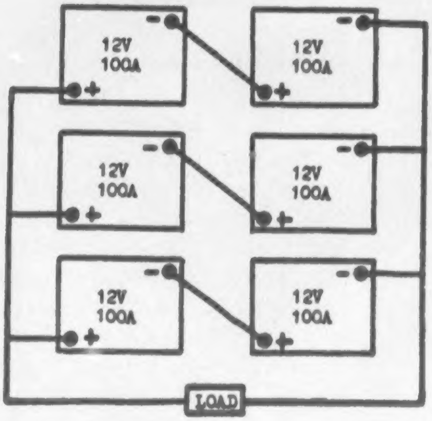
   a. 65.0
   b. 106.5
   c. 130.0

30. Which statement pertaining to specific gravity is true?

   a. Electrolyte used in tropical climates is more dense than that used in cold climates
   b. 1.280 electrolyte is 27 percent acid by weight
   c. Sulfuric acid is almost twice the weight of water

31. How much electrical power is being supplied to the load in the illustration?

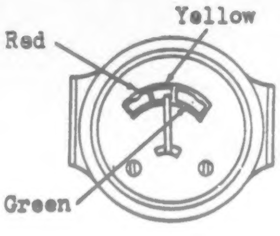
   a. 12 volts, 600 ampere-hours
   b. 24 volts, 300 ampere-hours
   c. 72 volts, 100 ampere-hours



## SECTION II. MAINTENANCE OF AUTOMOTIVE BATTERIES

9. **PREVENTIVE MAINTENANCE.** In nearly all cases of early failures of automotive batteries the cause can be traced to a lack of preventive maintenance. When given proper care batteries generally will give no trouble until they are worn out, unless damaged by accident or enemy action. The vehicle operator and the organizational level mechanic are responsible for performing preventive maintenance on the batteries of vehicles assigned to their unit.

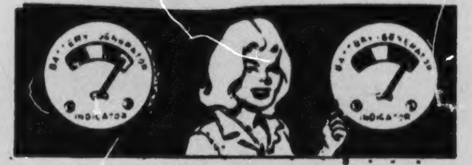
a. Each time the vehicle is started and then often during its operation the driver should check the battery-generator indicator, which is located on the dash panel. The battery-generator indicator is used on tactical vehicles and is a meter that shows the level of battery voltage. It has a scale that is marked off in three colors: red, yellow or amber, and green.



(1) When the ignition switch is first turned on, the indicator hand will usually point to the yellow section which is the center part of the scale. If the hand points to the red at the left side of the scale the battery is in a low state of charge. The hand may point to the green scale on the right if the battery was just recently charged at a high rate.

(2) If the battery charge is low the cause should be determined and any necessary corrections made. If a battery is allowed to remain in a low state of charge for very long, the sulfate formed in the plates will harden and it will be impossible or very difficult to return the battery to a fully charged condition.

(3) When the engine is started the battery-generator indicator hand will move to the right if the charging system is operating properly. The hand will point to the left half of the green part of the scale when the battery is fully charged. If the hand ever moves into the right half of the green scale the battery is being overcharged. (On some indicators this part of the scale is red instead of green.) The operator should then have the charging system checked immediately before the battery or charging system is damaged. Overcharging overheats the battery causing it to lose water at a fast rate and can warp the plates causing permanent damage.



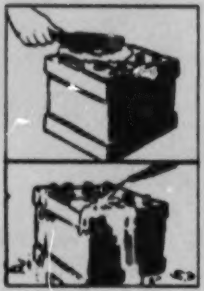
If the battery indicator shows this high during engine operation the batteries are being overcharged

(4) If the vehicle is equipped with an ammeter instead of a battery-generator indicator, the operator should check the position of the ammeter hand often during operation. For a fully charged battery, the ammeter should show a high rate of charge immediately after the vehicle is started. After about 15 minutes of operation the charge rate should drop to about 5 amperes. When the battery is partly discharged before starting, the high-charge rate will continue for a longer period. If the ammeter does not register a charge or if the high-charge rate continues, the charging circuit should be checked immediately.

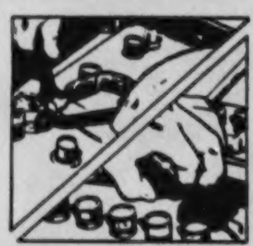
(5) After operation check the battery to see that it is clean, securely mounted, and not leaking. Cable terminals should be clean and secure on the battery posts. All vent caps should be present and tight.

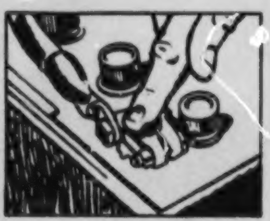
b. The batteries should be thoroughly inspected and serviced once a week by doing the procedures explained in paragraphs (1) through (6) below. Either the operator or the mechanic may be called upon to perform these procedures.

(1) Inspect the top of the batteries very carefully and clean them if needed. They must be kept clean to prevent them from discharging through collected dirt, etc. To clean, tighten the vent plugs and wash the batteries with a brush dipped in an alkaline solution, such as a mixture of bicarbonate of soda (baking soda) and water. Foaming will occur due to the reaction between the cleaning solution and battery electrolyte. After the foaming stops, rinse off the batteries with clean water and wipe dry with a clean cloth.


You scrub your battery top often with baking soda 'n' water and rinse 'er good after.

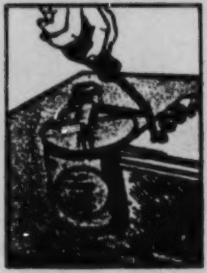
(2) Inspect the battery terminals to see that they are clean and the cable clamps are tight and free of corrosion. If they are corroded remove the cable clamps and clean the clamps and the battery posts with a solution like we described above. Then reconnect and tighten the cable clamps. Coat the terminals with a light coat of general purpose grease to fight off corrosion. Dirt will collect on the grease but it can be removed each time the batteries are cleaned and the terminals recoated with grease. When disconnecting the battery cables, always disconnect the ground cable first to prevent a short circuit. When connecting the cables connect the ground cable last.


You keep cable 'n' clamp hook-ups tight and clean.


You make sure there's a light coat of GAA on those connections to fight off corrosion.

(3) Remove and inspect the vent plugs to see that the ventholes are open. Use a short length of stiff wire to run through the ventholes to make sure they are not plugged, but be careful not to damage the check valves in vent plugs from waterproof batteries.

(4) Inspect the electrolyte level and add water if it is low. Filling instructions are usually located on the vent plugs or the cell covers. When correct, the electrolyte level will be at least 3/8 of an inch above the plates. Distilled water should be used to fill batteries if it is available; if it is not available, the second choice is rainwater. Do not store battery water in metal containers. Minerals that are found in water from streams or wells or from water stored in metal can damage and shorten the life of a battery. Water that is used for drinking purposes can be used, but only when distilled water or rainwater is not available. A battery will be damaged less by using clean water that has some minerals than by letting the electrolyte level drop below the top of the plates.



And you keep a sharp eye on that electrolyte level, adding clean water when needed to keep the plates covered and protected from air.

(5) Check the specific gravity of each cell with a hydrometer according to the instructions given in paragraph 5 of this lesson. If the specific gravity is at an acceptable level, perform a high-rate discharge according to instructions given in paragraph 7.

(6) Inspect the battery holddowns to make sure that the batteries are held properly in their carriers. If a battery is too loose it may bounce around and damage the container or shake the plates loose inside the cells. On the other hand, if the holddowns are drawn too tightly it may cause the container to crack.

**10. COLD WEATHER.** Battery capacity is greatly reduced by low temperatures because the electrolyte thickens and is less active. In addition, the engine is harder to crank so the starter motor requires more current. In order to perform satisfactorily in cold weather the battery must be kept in peak condition, so when the temperature drops you will have to keep a closer watch on the battery.

I'M NOT HALF THE BATTERY I USE TO BE.

a. In cold weather do not let the specific gravity drop below 1.250 if you fully expect the vehicle to start. When the temperature is colder than -20 degrees the vehicles should be stored inside where it is warm, if possible. If they must be parked outside the batteries should be heated during long periods of standby; otherwise, they will not take a charge or have enough capacity for normal use.

b. The electrolyte is also subject to freezing; the exact freezing point depends on the specific gravity. In a fully charged battery the electrolyte will freeze at -90 degrees. As the specific gravity drops, the freezing point rises. The following table shows the freezing point for various specific gravities.

| Specific gravity | Freezing point, degrees F |
|---|---|
| 1.000 | +32 |
| 1.100 | +19 |
| 1.150 | + 5 |
| 1.200 | -16 |
| 1.250 | -62 |
| 1.280 | -90 |

(1) If the battery electrolyte does freeze, the ice forces active material from the plates and can crack plates and containers or buckle plates and break separators. If you try to charge a frozen battery the grids expand and shed active material. Let a frozen battery thaw out in a room at normal temperature before charging. In this way the battery can be saved if freezing has not already caused too much damage.

(2) If water is added to a battery it may freeze if it is not immediately mixed with the electrolyte. For this reason, do not add water in freezing temperatures unless the battery is indoors or the vehicle is operated for at least an hour after the water is added.

11. TROPICAL CLIMATES. The high temperatures found in the tropics create their own maintenance problems that you will have to adjust to if you are assigned in one of these areas.

a. Rapid evaporation of the water will result due to the heat, so keep a close watch on the electrolyte level. Every effort should be made to keep the compartment, in which the batteries are installed, as cool as possible during and after operation. Do not obstruct ventilation holes or the heat will damage the batteries.

b. At high temperatures the acid in the electrolyte is more active, so using a weaker solution will give good results and cause less damage to the plates and separators.

(1) Electrolyte solution used for tropical climates should have a specific gravity of 1.200 to 1.225. You will have to weaken the solution yourself. Do this by drawing electrolyte from supply that is already mixed to 1.280 specific gravity and add battery water until the mixture has a specific gravity of 1.200 to 1.225. You will need to add about one quart of water to one gallon of electrolyte.

(2) If the battery was in use before it was sent to the tropics, change the electrolyte in the following manner. Make sure that the battery is fully charged, so there will be no acid left in the plates. Then remove the vent plugs and tip the battery upside down to drain all the old electrolyte. Refill the battery with electrolyte that has been weakened to 1.200 to 1.225 specific gravity. Be careful to avoid getting any of the electrolyte on yourself or your clothes. The acid can cause painful burns and will eat holes in your clothing.

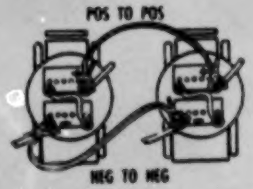
(3) The following table shows various specific gravities and the state of charge for batteries that contain weakened electrolyte for use in the tropics.

| Specific gravity of electrolyte used in tropical climates | State of battery charge |
|---|---|
| 1.200 - 1.225 | Fully charged |
| 1.180 | 75% |
| 1.135 | 50% |
| 1.090 | 25% |
| 1.045 | Discharged |

(4) When the electrolyte in a battery has been weakened, a tag showing the full charge specific gravity should be attached to the battery. These batteries should also be identified by painting a white dot about 1 inch in diameter on the top of the battery where it can be easily seen. Do not put the paint on top of the service date that is stamped on the battery.

12. SLAVING. Normally the charging system of a vehicle will keep the vehicle's batteries charged. Occasionally, due to excessive cranking, repeated short drives, or a fault in the electrical system the batteries will become discharged. If the vehicle is located in the field where no external method of charging is available, you will probably have to start it by towing or slaving the electrical system of another vehicle. We will not discuss towing in this lesson.

a. To slave a vehicle with discharged batteries you must use heavy-duty jumper cables and connect its dead batteries to the good batteries of a second vehicle. Stay alert when connecting the jumper cables. The hookup must always be positive to positive and negative to negative. If either of the vehicles has an AC charging system, the rectifier will be burned out if you just momentarily touch the cables to the wrong terminals.

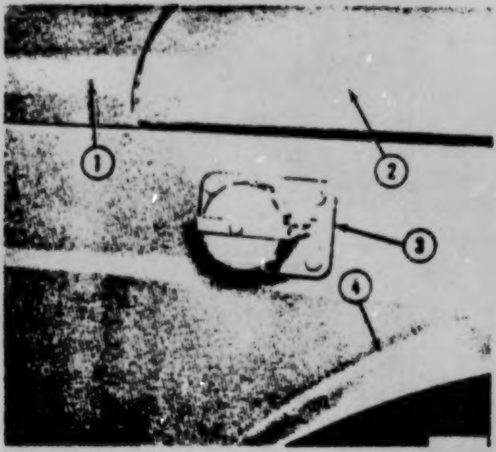


(1) Never try to slave one vehicle from another one that has a power source with a smaller ampere-hour capacity rating. In other words, do not slave a 10-ton tractor with four 6TN 100 ampere-hour batteries from a 1/4-ton truck with two 2HN 45 ampere-hour batteries. This will only lead to more trouble.

(2) After connecting the jumper cables it will be helpful if you run the live vehicle with good batteries at 1,800 RPM for a short while. This allows its charging system to put a slight charge in the discharged batteries which will help a lot when attempting to crank the dead vehicle. While cranking the dead vehicle keep the live one running at 1,800 RPM so you can use the power created by its generator.

(3) Remember that batteries will be damaged if left in a discharged state for long. After you get the slaved vehicle started make sure that the vehicle is kept in operation long enough to fully recharge the batteries. If this is not possible, make provisions so the batteries can be charged from an external source. If a defect caused the batteries to discharge, get it corrected immediately.

b. Some vehicles are equipped with slave receptacles so a slave (jumper) cable can be easily plugged in. Both vehicles involved in the slaving must be equipped with receptacles. A special two-conductor slave cable that fits the receptacles is provided. The proper positive to positive and negative to negative connection for slaving is made by just plugging the one piece slave cable into the slave receptacles of the two vehicles.



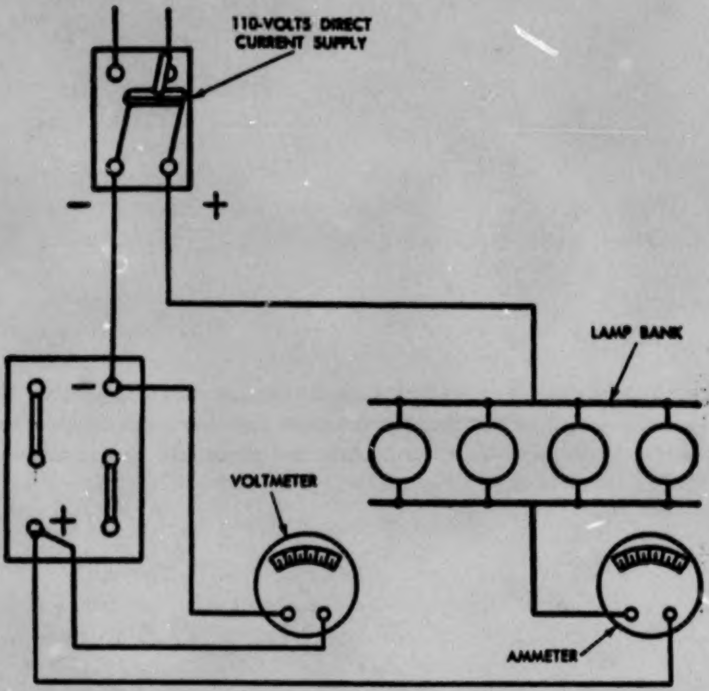
1 Cowl
2 Hood

3 Slave receptacle
4 Right front fender

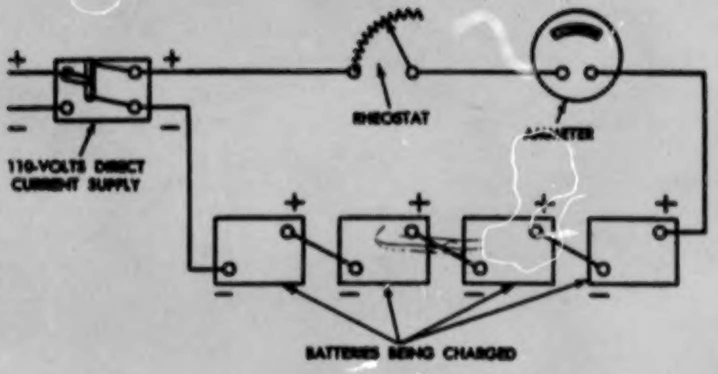
13. CHARGING METHODS. Anytime the gravity of a battery drops below 1.225 (1.135 in tropical climates) it is best to recharge it with a battery charger under controlled conditions. The two principal ways of charging are constant current and constant potential (voltage). The method used will depend on the equipment and facilities available.

a. Constant current charging is usually done only at installations where a regular battery shop is set up. Electrical power for the charging current is furnished by the 110-volt supply that is supplied by the high lines. Since the 110-volt supply is usually always AC, which will not charge batteries, it must be changed to DC. This is usually done by rectifiers.

(1) After the incoming 110-volt power has been changed to DC it must not be connected directly to a single 12-volt battery or the battery will be ruined. A resistance must be placed in the circuit to limit the current. This can be done by connecting a number of lamps in parallel as shown here. A 110-volt, 100-watt lamp consumes about 1 ampere of current, so four bulbs as shown here will permit 4 amperes to flow. A variable resistor of the proper value can be used in place of the lamps and adjusted to give the desired current.



(2) Several batteries are generally connected in series when charging by the constant current method so the power that is consumed by the current limiting resistance is reduced. When connecting the batteries their combined voltage should never be higher than the charging voltage. Allow 2.5 volts per cell when adding up the battery voltage. All batteries in the same series should be in about the same condition. Batteries being charged by the constant current method must be checked often, particularly in the final stages, to prevent overcharging.



b. Battery chargers supplied for use in the field are the constant potential type. A charger usually consists of a DC generator powered by a gasoline engine. They are made with 7-1/2- and 15-volt outputs or with a 15- and a 28-volt output.

(1) When using the battery charger to charge one 12-volt battery, connect its 15-volt output or load terminals to the battery terminals. Connections must be positive to positive and negative to negative. If more than one battery is to be charged from the 15-volt output they must be connected in parallel. If you connect the batteries in series their voltage will be higher than the charging voltage and the charger could not force current through the batteries.

(2) To charge 12-volt batteries from the 28-volt output of a charger, connect two batteries in series, then connect them to the 28-volt load terminals. To charge more than two batteries they must be connected in series-parallel. The batteries in each series group should be in about the same condition.

(3) When a battery is first placed on a constant potential charging system its voltage is much lower than the charging voltage, so a high current will flow. As the battery is charged its voltage increases, but the charging voltage remains constant. This causes the current to decrease as the battery is charged and in the end will taper off to a very slow rate. Less attention is required near the end, but care must be taken to prevent overheating the battery at first. The constant potential battery chargers are generally equipped with a variable resistor so the operator has some control over the charging rate.

**14. CHARGING PROCEDURES.** Batteries should only be charged in the open air or a well-ventilated room due to the gases they expel. Before attempting to charge a battery give it a thorough cleaning and inspection. Don't waste your time on batteries that are cracked or damaged in any way that will make them unserviceable. Place good batteries on a board or wooden rack, never stack them on top of each other or on the ground or a concrete floor.

a. Check and record the specific gravity of each cell of all the batteries to be charged. Add water to bring the electrolyte to the proper level. Arrange and connect the batteries for charging. All batteries connected in one series group should have about the same specific gravity readings. Make sure all the vent plugs are secure and the vents not plugged, then begin the charge.

b. Watch closely for overheating or excessive gassing for the first few minutes of charge. If either occurs, reduce the charging rate. For best results the battery electrolyte should not exceed 110 degrees temperature. The battery should gas very little when it is first placed on charge, but steady gassing later on when the battery nears full charge is normal.

c. Check the specific gravity of the battery often while it is being charged. Just how often will depend on the rate of charge. If a charge rate of 2-1/2 amperes for 2HN batteries or 5 amperes for 6TN batteries is being used, check the gravity hourly when the batteries near full charge. You may reduce the time between checks if the charge rate is decreased. Add water to replace any lost during the charge. A battery is fully charged when three successive hydrometer readings show no further rise in specific gravity.

d. When the battery is charged remove it from the charger and clean its top to remove any acid. Inspect the battery once again for any cracks that may have opened due to the charging process. Screw the vent plugs tightly in place. If the battery has handles and the paint on them is worn, apply a coat of acid-resistant black paint.

**15. PLACING BATTERIES IN SERVICE.** New batteries that you receive will probably be charged and dry. If they are you will have to fill them with electrolyte in preparing them for service. Instructions are generally received with new batteries on how to prepare them for service and should always be followed. In general, the following instructions apply:

a. Remove and destroy the sealing devices from the ventholes of the vent plugs. Remove the vent plugs and fill each cell with electrolyte to the proper level. The temperature of the battery and electrolyte must be at least 60 degrees. Let the battery stand for 30 minutes after filling to allow the plates and separators to become soaked, then check the specific gravity of each cell. The electrolyte level must be correct.

b. The battery is now ready for use unless one or more of the following conditions exist:

(1) The specific gravity of any cell is below 1.250 after the 30-minute stand.

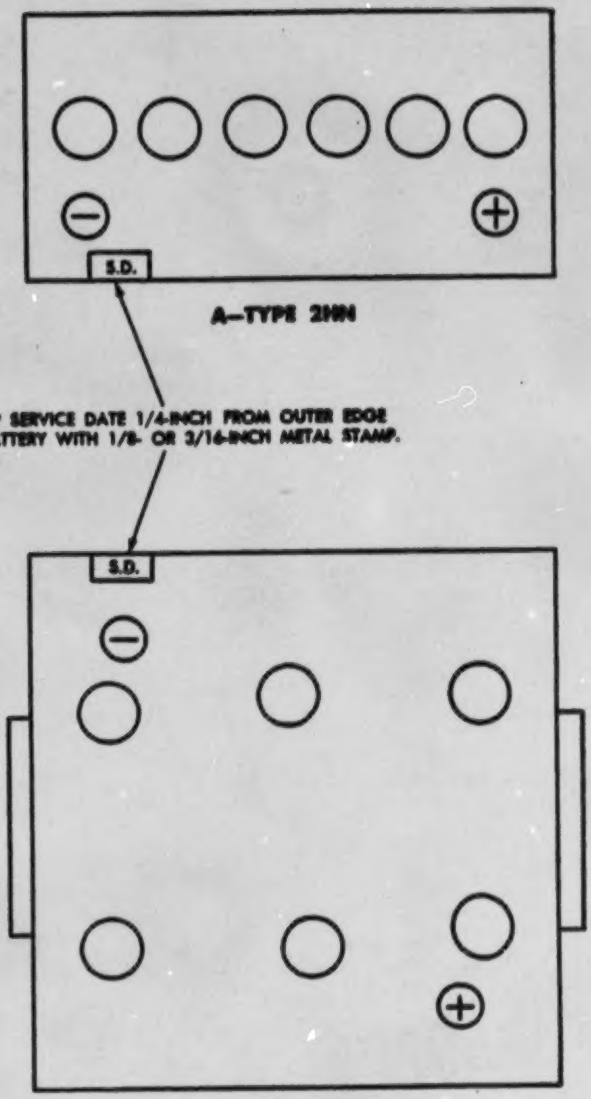
(2) The battery will not be used for 12 hours after filling.

(3) The battery is going into service in temperatures below 0 degrees.

c. If any of the above conditions exist, the battery must be charged. If you have the time and equipment it is always best to charge the battery regardless of the conditions to insure longer service life. After charging, the specific gravity should be at or very near 1.280.

d. At the time the battery is prepared for service it must have a service date stamped on it. This is so that its age can be determined at a later date. Stamp the date with 1/8-inch or 3/16-inch metal stamps at the location shown in the accompanying illustration. The date will consist of the letter S followed by the month and year. For example, if the battery was prepared in January 1970 the date will be S-1-70.

e. When selecting batteries for installation in a vehicle they should be matched. This applies to both new and charged batteries. If two batteries with one weaker than the other are placed in a vehicle, the vehicle's charging system will overcharge the stronger battery in an attempt to charge the weak one. This causes overheating and loss of water in the stronger battery shortening its lifespan. In matching batteries you should pair batteries that have about the same specific gravity and voltage.



S.D.
S.D.

A—TYPE 2HN

STAMP SERVICE DATE 1/4-INCH FROM OUTER EDGE OF BATTERY WITH 1/8- OR 3/16-INCH METAL STAMP.

B—TYPE 6TN

Note. - Complete exercises 32 through 40 before continuing to section III.

32. The level of the electrolyte above the battery plates should be at least

    a. 1/8 inch.
    b. 3/8 inch.
    c. 3/4 inch.

33. Batteries and cables that have become corroded should be washed in a solution of water and

    a. ammonia.
    b. sulfuric acid.
    c. baking soda.

34. Which output of a constant potential battery charger should be used to charge four 12-volt batteries connected in parallel?

    a. 7.5 volts
    b. 15 volts
    c. 28 volts

35. What is the percentage of charge of a battery if it has a 1-inch white dot on its top and a specific gravity of 1.220?

    a. 50
    b. 75
    c. 100

36. Which component is most likely to be damaged when interconnecting the electrical systems of two vehicles if the jumper cables are improperly connected?

    a. Switch
    b. Starter
    c. Rectifier

37. A new dry-charged battery MUST be charged before it is put into service if the

    a. specific gravity is 1.250.
    b. temperature is -20° F.
    c. vehicle is to be operated immediately.

38. What do the characters S-6-67 mean when found stamped on a battery?

    a. The battery was put in service in June 1967
    b. The electrolyte was mixed for summer use in 1967
    c. It is the manufacturer's serial number

39. When charging a battery, what is indicated if the battery is gassing steadily and the specific gravity is 1.240?

    a. The battery is charging normally
    b. The charge rate is too high
    c. The charge rate is too low

40. What should be done if the battery electrolyte freezes?

    a. Let it thaw out at room temperature
    b. Charge the battery at a slow rate
    c. Add acid to lower the freezing point

## SECTION III. CONCLUSION

### 16. SUMMARY.

a. The cell of an automotive battery consists of two unlike metals, spongy lead and lead peroxide, immersed in an electrolyte solution consisting of water and sulfuric acid. The common 12-volt battery has 6 cells connected in series. As the battery discharges and is charged the specific gravity of the electrolyte changes, enabling its state of charge to be determined by specific gravity readings taken with a hydrometer.

b. Both the voltage and the capacity must be considered when determining the correct battery for a particular vehicle. The capacity of automotive batteries is determined by the 20-hour rating. Batteries must be connected in series to increase the voltage and in parallel to increase the capacity rating.

c. Preventive maintenance on batteries is performed by daily checks by the operator and by weekly inspections that may be performed by either the operator or the organizational mechanic. Due to the increased current requirements, reduced efficiency of the battery, and the possibility of freezing, the battery must be kept in peak condition in cold weather. Battery life is extended in tropical climates by weakening the electrolyte solution.

99

d. A vehicle with discharged batteries can be started by slaving its electrical system from the electrical system of a live vehicle, but the batteries must be charged after starting. Of the two-methods of charging, constant current and constant potential, the organizational level mechanic will most likely use the constant potential method. When charging, regular checks are made on the battery's specific gravity, temperature, and electrolyte level.

e. When replacing batteries, the mechanic will prepare them for service. If either new or charged batteries are used, batteries should be matched in each vehicle according to their condition.

17. PRACTICE TASK LIST DIRECTIONS. Appendix A contains a list of tasks associated with automotive batteries. They are representative of the tasks you will be required to perform as a wheeled vehicle mechanic. Perform all the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

## APPENDIX A

## PRACTICE TASK LIST

Practice Objective. After practicing the following tasks you will be able to:

1. Perform preventive maintenance on batteries.
2. Use jumper cables to connect the electrical systems of two vehicles together.
3. Use the equipment available in your unit to charge batteries.
4. Install batteries.

Tasks.

1. Perform weekly preventive maintenance services on batteries of vehicles in your unit. These services include:

    a. Inspecting and cleaning the batteries.

    b. Inspecting and cleaning the battery terminals and cable clamps.

    c. Checking the vent plugs.

    d. Correcting the electrolyte level.

    e. Testing the specific gravity.

    f. Inspecting the battery holddowns.

2. Select two wheeled vehicles used in your unit and connect their electrical systems with jumper cables as you would for slaving purposes. Points that you should consider are:

    a. The voltage and capacity ratings of the batteries.

    b. Proper polarity when connecting the jumper cables.

3. Locate the battery charger issued to your unit and proceed as follows.

a. Study the instruction booklet that accompanies the battery charger.

b. Discuss any instructions that you don't understand with qualified personnel in your unit.

c. Ask to be allowed to assist and to charge batteries when the occasion arises.

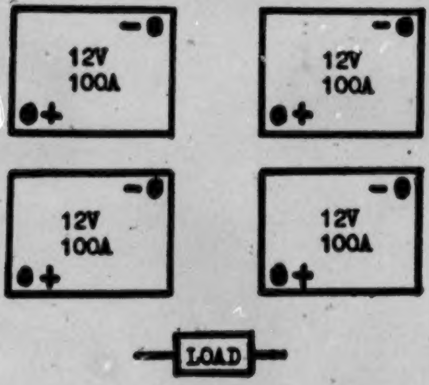
4. Obtain and study an instruction sheet that accompanies new batteries supplied to your unit. Determine how you would go about carrying out each procedure in the instruction sheet and examine a new battery.

5. Locate the service date on several batteries on vehicles in your unit and determine the age (in months) of each battery.

6. Locate the metal stamps that your unit has for stamping the service date on batteries and practice using them on an old discarded battery or a block of wood.

7. Examine the battery cable connections in several vehicles and determine if the batteries are connected in series or series-parallel.

8. Draw lines to connect the batteries shown below to produce a power supply of 24 volts and 200 ampere-hours.



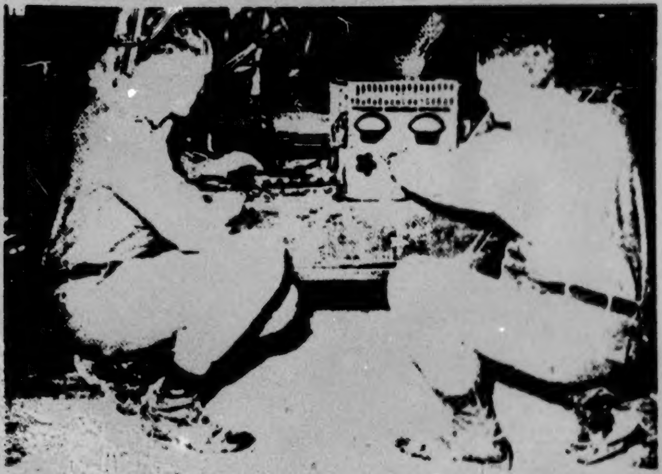
# APPENDIX B

## REFERENCES

| | | |
|---|---|---|
| TM 9-6140-200-12 | Operator and Organizational Maintenance Manual for Lead-Acid Storage Batteries | Sep 73 |
| TM 9-8000 | Principles of Automotive Vehicles | Jan 56 |

# ENLISTED MOS
# CORRESPONDENCE/OJT COURSE

## ORDNANCE SUBCOURSE 63B203



## LESSON 3
## FUNDAMENTALS OF ELECTRICAL TESTING EQUIPMENT

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DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

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# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

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|---|---|
| **Ordnance Subcourse** 63B203 | Wheeled Vehicle Electrical Systems |
| **Lesson** 3. | Fundamentals of Electrical Testing Equipment |
| **Credit Hours** | Four |
| **Lesson Objective** | After studying this lesson you will be able to:<br>1. Describe the voltmeter, ammeter, and ohmmeter.<br>2. State how the voltmeter, ammeter, and ohmmeter work and how each is used.<br>3. Explain the purpose of the low-voltage circuit tester and its components.<br>4. State the location of the low-voltage circuit tester components and how they are connected to an electrical circuit.<br>5. Describe the two general types of multimeters and explain their purpose and use. |

6. Explain how multimeters are used to test automotive electrical systems.

**Study Assignment** . . . . . . . . . . . . Study the lesson thoroughly. It will provide you with the knowledge you need to select and use some of the electrical test equipment you will have to work with. A knowledge of the purpose and use of these different pieces of test equipment is needed so that you can quickly locate trouble that may show up in the electrical systems of the vehicles you work on.

**Materials Required** . . . . . . . . . . . All students. Exercise response list and answer sheet. Correspondence/OJT option students. See appendix A.

**Suggestions** . . . . . . . . . . . . . . . . Study the lesson carefully. If you are in a unit with test equipment, look over the actual items.

## STUDY TEXT

## SECTION I. PRINCIPLES OF METERS

### 1. INTRODUCTION.

a. If man did not know how to measure where would he be? Throughout each day he makes various measurements. For example, he stops eating before he gets sick. He squeezes out or measures the right amount of toothpaste onto the toothbrush. When he goes grocery shopping, the grocer measures the weights, lengths, and sizes of the groceries before he delivers them to the customer.

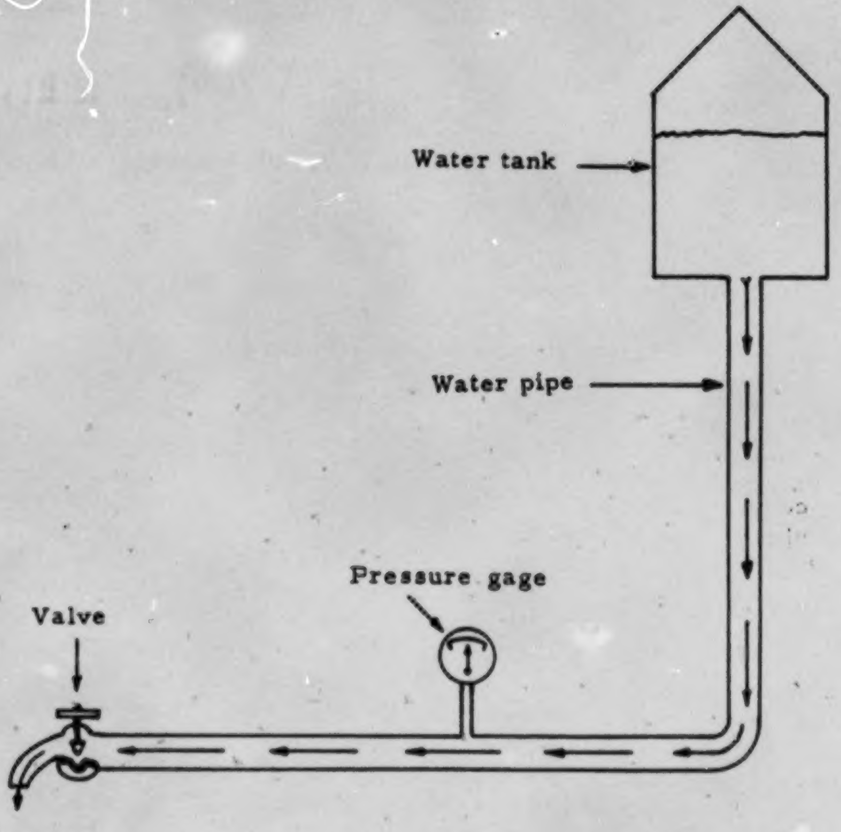
b. Another example of measurement applies to the water and electricity supplied to our homes. These measurements are made with meters. Some of the meters measure how much you use and are called volume or flowmeters. Your water and electricity bills are based on these meter readings. You have probably seen at least one of these meters as the electricity meter should be mounted on your house in plain view. These flowmeters, which are read by the "meter man," are only one of the many types of measuring devices needed to show service personnel how a system is operating. Both water and electricity systems work best in a certain pressure range. Both systems, therefore, include pressure measuring devices at various points along the line.

c. Automotive electrical systems also require various measurements to indicate how they are operating. The automotive electrical system actually resembles the water system in your home in many ways. As you study this lesson you will find that the automotive electrical system can be measured in the same manner as the home water system. Let's see how this is possible. We will start with an electrical pressure measuring device.

2. VOLTMETER. You learned in an earlier lesson that voltage is measured with a voltmeter. Let's find out how voltage compares with part of a water system and how a measurement is made. A WORD OF CAUTION! Always remove all jewelry such as wristwatches and rings before making any test on electrical equipment. These metal items could cause you to be shocked or burned.

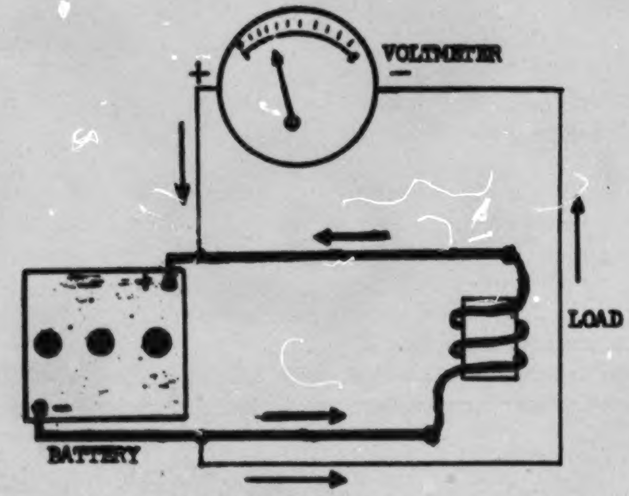
a. Have you ever opened the valve or spigot at your bathroom sink and the water flowed very slowly? Then, the next time you opened the valve a few hours later the waterflow was back to normal. The problem was probably due to a pressure loss in the water system. If you could have looked at a pressure gage on the water system, you would have found the pressure was lower than normal when the water flowed too slowly. This tells you that the pressure in a water system affects the flow. The same is true of an automotive electrical system. When the pressure (voltage) drops, it causes the flow (current) to also drop. This makes electrical components work improperly. For example, electric motors would run too slow, solenoids or electromagnets would not have enough strength to operate, and lights and lamps would not burn bright enough.

b. When an electrical system does not work properly the good repairman does not guess what's wrong. He makes measurements on the system. One of the measurements he will make is a voltage measurement or test. He will use a voltmeter for this test. He'll connect the voltmeter to the electrical system in the same manner that a pressure gage is connected to a water system. This is because both instruments are measuring pressure. If you look at the illustration of the simple water system you will notice a pressure gage connected to the water pipe. The pipe carries the water from its supply (water tank) to the valve. You should notice that the pressure gage is connected to receive the same pressure as that in the pipe. It is connected parallel to the water system. The same is true of the voltmeter—it is always connected parallel to an electrical circuit. Let's see how this is done.



Measuring the water pressure in a simple water system

c. Let's compare a simple electrical system to a simple water system and see how the voltemeter measures pressure. You should notice that the electrical system, in the accompanying illustration, contains a battery on the left. The battery is connected to the load on the right. The load could be any electrical component such as a light bulb, electromagnet or an electric motor. The current flows from the battery to the load, then through the load and back to the battery. Like the water system, the electrical pressure gage or voltmeter must sample the pressure or voltage in this circuit.



d. The voltmeter, which has two connections, is connected to the electrical circuit in the following manner. One connection is connected to the positive side of the circuit and the other is connected to the negative side of the circuit. These connections then become the positive side and the negative side of the voltmeter. By connecting the voltmeter in this manner, equal voltage is applied to both the voltmeter and the load. The flow of electricity or current now has two paths to follow. One path is through the load (indicated by heavy arrows) and the other path is through the meter (light arrows). The wires in the meter are very long and small in diameter making the resistance high. This means very little current will flow through the meter. The resistance of the load varies depending on the type of load such as a small lamp compared to a large motor. However, the resistance of the load is generally less than that of the meter. For this reason, most of the current in the circuit flows through the load. As you can see, the two paths are side by side or parallel. This is why we say the voltmeter is connected parallel to the circuit.

e. The voltmeter contains a pointer or hand called the indicating pointer. This pointer is connected to an electromagnet. The pointer and electromagnet are mounted on a pivot or hinge pin and can be moved or swung around like a door. A very small coil spring, called a hairspring, holds the pointer on zero when the meter is not in use. It also returns the pointer to zero when the meter is in use and the voltage stops or the meter is disconnected. When voltage is applied to the voltmeter, it moves the current through the electromagnet. The electromagnet then forces or moves the pointer away from zero. The amount it moves depends on how much voltage is applied. This is because as the voltage is increased the current will increase, and as the voltage decreases so does the current decrease. The more pressure or voltage that is applied to the circuit, the more current that will flow and the voltmeter will therefore change as the voltage changes. The main thing to remember when using a voltmeter is that it is connected parallel to the main circuit.

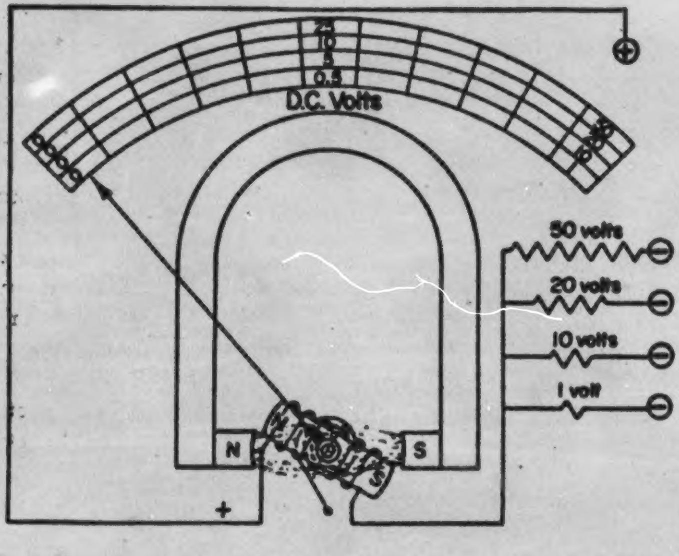
f. If the voltmeter were connected so that all the current within a circuit passed through the meter it would be connected in series. If the voltmeter were accidentally connected in this manner, it would in most cases indicate the source voltage. However, the load component(s) would not operate normally due to the high resistance the voltmeter placed on the circuit. When the voltmeter is used to test a battery with no load applied, positive is connected to positive and negative is connected to negative. However, in this case the meter and the battery make up the complete circuit.

g. Voltmeters do not all look alike. There are many types and sizes of voltmeters. For example, large complex electrical equipments have built-in voltmeters. This is generally because a slight variation in voltage will greatly affect the operation of this equipment. Operators or service personnel must constantly measure the voltage on this equipment and make quick adjustments whenever needed. Automotive electrical systems are not quite as sensitive and are designed for more variation in voltage. Therefore, built-in voltmeters are not needed on vehicles. Should the voltage vary more than is allowed or if the voltage is thought to be wrong, portable voltmeters are available to measure the voltage. Some voltmeters are in separate cases while others are part of a combination-type meter. Two good examples of combination meters are the low-voltage circuit tester and the multimeter. These combination meters are covered later in this lesson.

h. Voltmeters vary depending on their model and use. For example, some voltmeters have only one scale where others have two or more scales. A voltmeter with only one scale is limited in its use, whereas one with many scales has many more uses. Now you are beginning to wonder how the meter is connected to a circuit if it has more than one scale. Does it have more than two test leads? No, it doesn't. It has only two test leads. Let's see how this is possible.

i. All portable voltmeters include flexible test leads which are merely a length of wire. Each has a male plug on the meter end and a test probe or an alligator clip on the other end. The test leads are usually color coded red and black. The red lead is connected to the positive terminal on the meter and the positive side of the circuit to be tested. The black lead is used to connect the negative terminal of the meter to the negative side of the circuit. Now let's see how the two test leads are used with voltmeters with two or more scales or ranges.

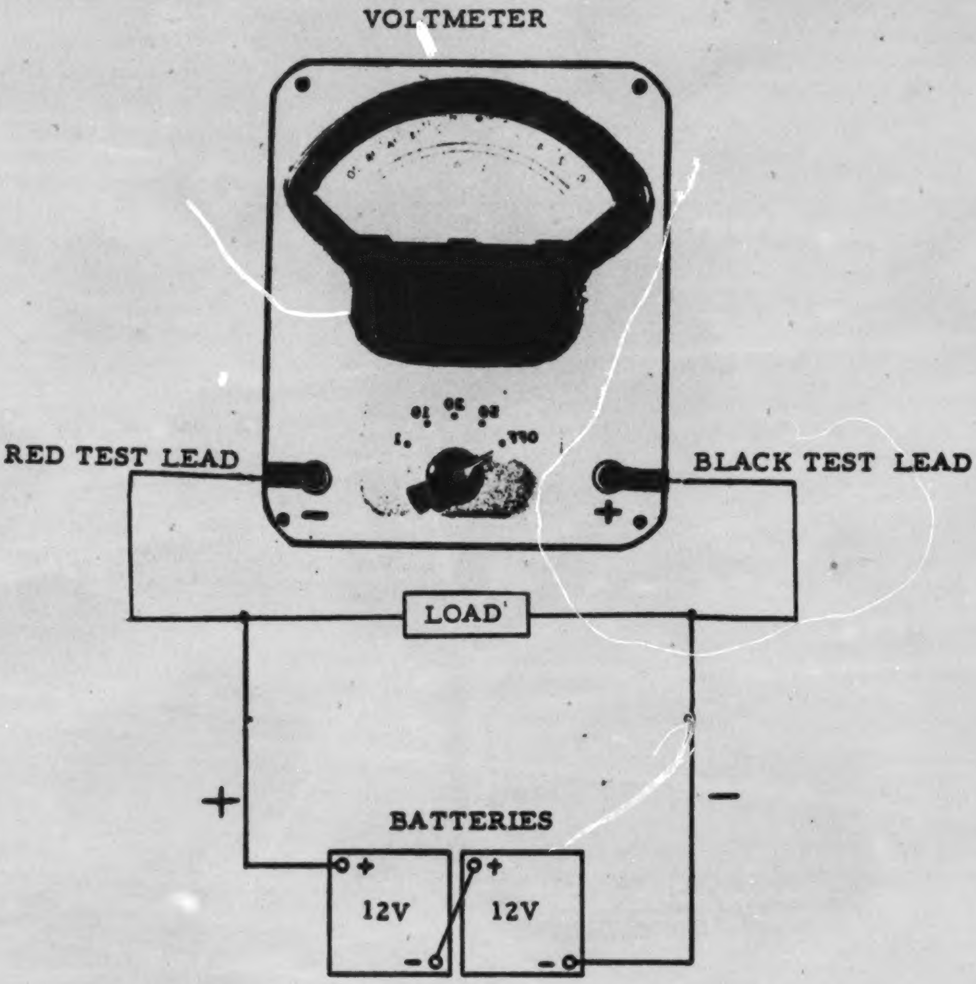
j. Two methods are used to connect the two test leads to the meter so that all ranges can be used. In one method, the test leads are always connected to the same two terminal sockets of the meter and a selector switch is used to select the proper range. The second method uses one common terminal for the negative or positive lead, and the other lead is connected to a different terminal for each range.



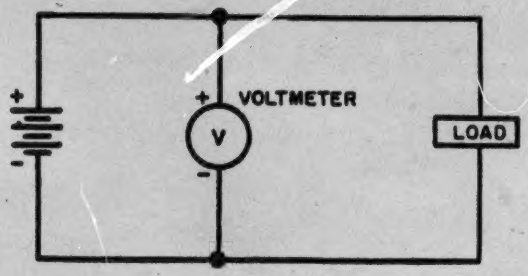
Multiscale voltmeter.

k. Why do we need more than one range on a voltmeter? Why not have one range from say 0 to 500 volts? This type meter would not be practical. Generally electrical test meters are most accurate in the center of the scale or range. This means the 0-500 volt scale would be most accurate around 250 volts. The battery-generator voltage of most military vehicles is in the 24- to 28-volt range. You will therefore be using the voltmeter to test voltages ranging from 50 volts to a fraction of 1 volt. Let's see how you would use a voltmeter with more than one range to test various voltages.

1. Suppose you were issued a voltmeter similar to the one in the accompanying illustration. Do you think you could use it? You should notice that while the meter dial contains 3 ranges or scales, the selector switch indicates there are actually 4 ranges. The ranges on this voltmeter are respectively 0-1 volt, 0-10 volts, 0-20 volts, and 0-50 volts. The range or scale for 0-10 volts can also be accurately used when the selector switch is in the 0 to 1 volt position. The numbers on the 0-10 volt scale then become tenths of a volt. For example, 2 becomes 0.2 (two tenths) of a volt, 3 becomes 0.3 volt and 10 becomes 1.0 volt. Let's go through the steps you would use to connect this voltmeter to a circuit.



m. Let's assume you want to test the voltage in the circuit in this illustration which includes a 24-volt set of batteries. You should first make sure the selector switch is off. Then connect the test leads to the meter as in the illustration. The red lead connects to the positive (+) terminal and the black lead to the negative (-) terminal. Next connect the leads to the circuit to be tested. Remember, parallel or across the circuit. Connect the red lead to the positive side and the black lead to the negative side. Now you are ready to measure the voltage. Turn the selector switch to 50 and you have connected the meter to the circuit. If the battery is charged and the load in the circuit is small, such as a small bulb, the meter should indicate close to 24 volts. Notice this is about the center of this scale. Let's say you are checking a defective 24-volt circuit with a heavy load such as a starter. When you switch the selector to 50 the meter only indicates approximately (about) 12 volts. If you want to get a more exact measurement, switch the selector to 20. You are now using the 0-20 scale and it is easier to read for this particular voltage. CAUTION—you must turn the selector switch back to 50 or off BEFORE this heavy load is disconnected from the circuit. If you don't, the meter will be damaged if the voltage jumps past 20 volts when the load is disconnected. You should notice that ranges for the selector switch start with the highest range 0-50. As the selector is turned to the right, the ranges become smaller. This prevents burnout of the meter by the operator having to go through the higher ranges first, once he leaves the off position.



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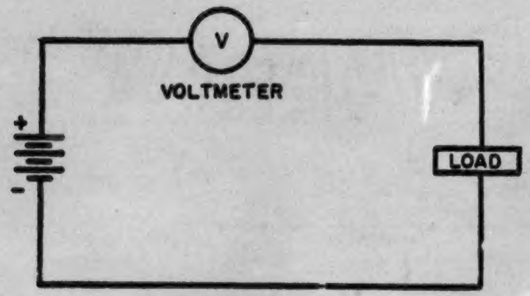

INCORRECT B

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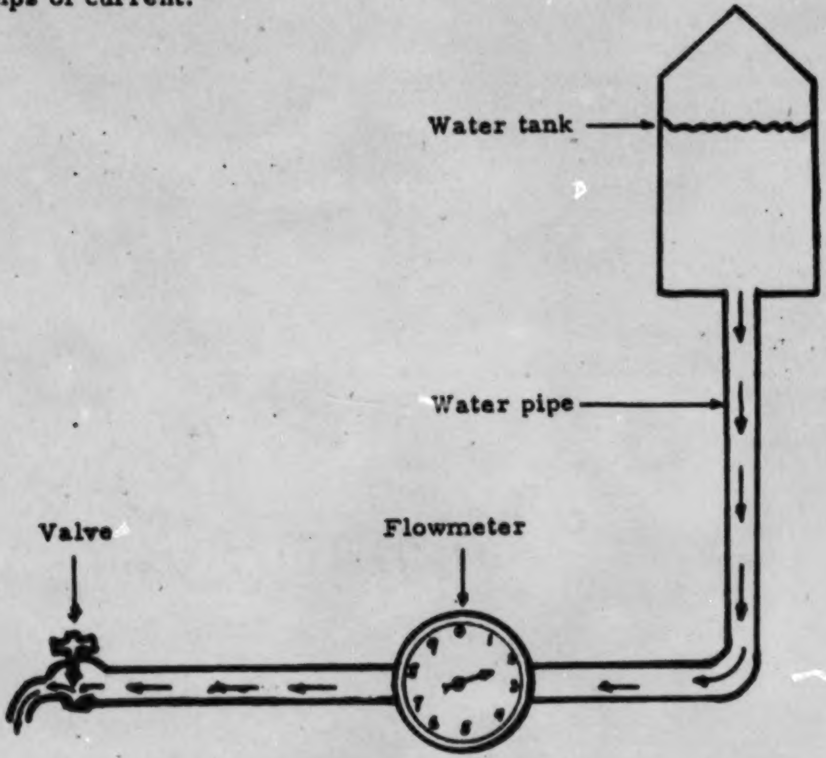
n. Let's look at what we have learned so far. We learned that the automotive electrical system is in many ways similar to a water system. We learned that electrical pressure is measured with a voltmeter like water pressure is measured with a pressure gage. We have also learned how a voltmeter is connected to an electrical circuit. As we learned before, this is only one measurement of many that can be made on the automotive electrical system. Let's next see how current can be measured with an ammeter.

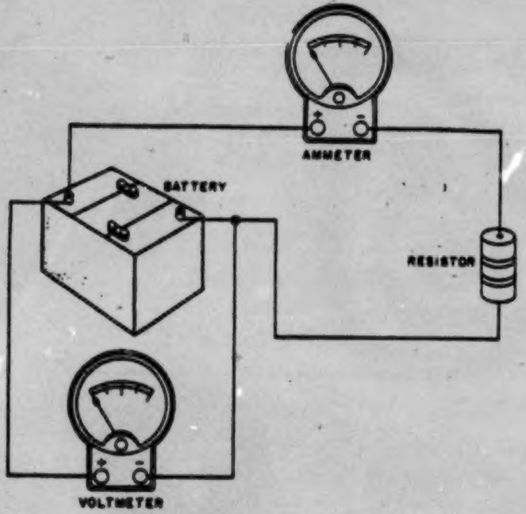
3. AMMETERS. If we want to find out how much water is flowing through the pipe in a water system, we would have to install a flowmeter. The flowmeter would have to be placed in the pipe in such a way that all of the water moving through the pipe would go through the meter. The meter would "count" (measure) the number of gallons of water that moved through it.

a. The ammeter does the same thing in an electrical circuit that the flowmeter does in the water pipe. The ammeter measures the amount of current moving through the wire. While the flowmeter measures the water flow in gallons, the ammeter measures the electrical current in amperes. The gallon is a unit of measure for water and other liquids; the ampere is a unit of measure for electrical current. Amperes are often called "amps" or "amps of current."



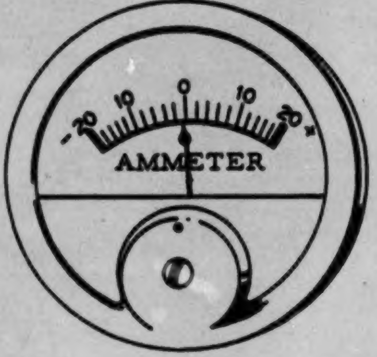
Measuring the water flow.

b. In order for the ammeter to show the amount of current flowing, it must be placed in the electrical circuit in such a way that all of the current flows through it. To do this it is necessary to break the circuit and connect the ammeter into it. The electrical term for this type of connection is "series." A series circuit is one that has only 1 path or wire through which the current can flow. An ammeter is always connected in series so it can measure the amount of current (amperage) flowing. The accompanying illustration shows the right way to install an ammeter. Notice that the right way to install an ammeter is opposite from the right way to install a voltmeter.

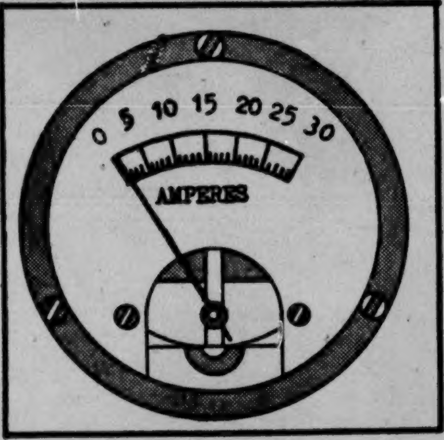


c. Ammeters are found in three general types.

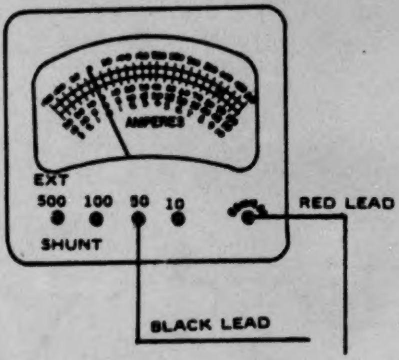
(1) The first is the type used in the instrument panel of some automobiles and trucks. This particular ammeter can be identified by the zero in the center of the scale and equal numbers to each side of the zero. A minus or negative symbol (-) or the word discharge is located at the far left of the numbers. A positive symbol (+) or the word charge is located to the far right of the numbers. The purpose of this ammeter is to show the operator whether the battery is being charged or discharged.



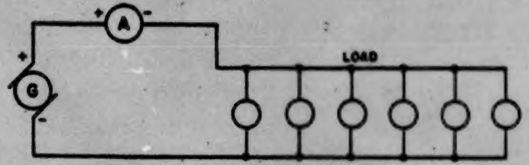
(2) A second type of ammeter can be identified by the zero located at the left side of the dial and numbers increasing to the right side of the dial. This ammeter is found on many battery chargers. Its purpose is to show the rate at which the battery is being charged. The third type ammeter is found in most automotive testing equipment. It can be identified by the zero being located close to the left end of the scale and the numbers increasing on each side of the zero. The right side increases much more than the left. Let's find out what this ammeter looks like and how it is used.



d. The ammeter resembles the voltmeter in many ways. It may contain one or more scales on its face or dial. Ammeters with only one scale, like the voltmeters, are limited in their use. Ammeters with two or more scales generally have a terminal connection for each scale rather than a selector switch. This is especially true if the ammeter is made to measure high amperage. Ammeters with terminal connections for each range have one common terminal. One test lead is connected to this terminal; the other is connected to the terminal of the range desired. The ammeter, like the voltmeter, may be found as a separate meter or part of a test instrument containing other types of test meters and test equipment. A good example of this can be seen in the low-voltage circuit tester section of this lesson.

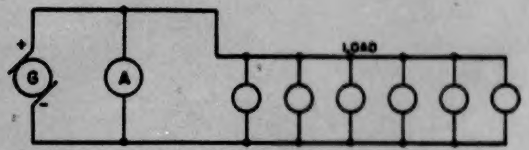


e. The electrical portion of the ammeter must be constructed heavy enough or in such a manner that it will handle the amperage it must test. An internal shunt or resistor is built into many ammeters to help them carry the current. Some ammeters are used to test quite high amperage. In this case, the meter is made to connect an external shunt or resistor to make the test. This is the purpose of the exterior-shunt terminals on many ammeters. When the electrical leads are connected to these terminals, the external shunt assembly is included in the meter circuit. Care must be taken that all ammeter leads are connected to the meter in the right polarity (red to positive, black to negative). As you now know, the circuit must be broken and the ammeter connected in series so that all the current will pass through the ammeter or the external shunt.



AMMETERS ARE CONNECTED IN ONE WIRE OF THE LINE
RIGHT

A

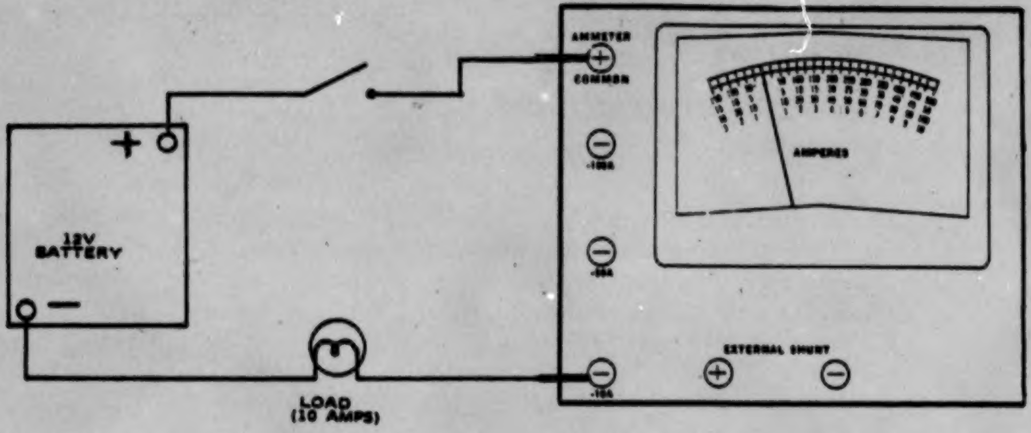


AMMETERS SHOULD NEVER BE CONNECTED ACROSS THE TWO WIRES OF THE LINE
WRONG

B

f. An ammeter is quite easy to use; however, here are some facts you should first think about. You should never try to connect the ammeter into a circuit under load. This will cause an arcing when the test leads are connected which could injure you as well as damage the equipment. This is especially true if the circuit carries a heavy amperage load. The load can generally be disconnected by opening a switch. The ammeter should never be connected while the engine is running. It's best to make sure that all switches are turned off including the master (battery) switch. You should also try to determine the amount of amperes or current that you are going to measure. This information can be found in the vehicle technical manuals. In the event you are not able to find what amperage the circuit does carry, you can start with the highest range on the ammeter and work down. Through this method you will not damage the ammeter by using a range too small to handle the amperage. In fact, it is always best to start testing on the scale higher than you think is necessary for a particular circuit.

g. Let's follow the hookup of the ammeter in the accompanying illustration. The circuit has a fully charged 12-volt battery, a load, and a switch to connect or disconnect the load to or from the battery. The load is a large lamp similar to the headlamps on a vehicle. The information included with this circuit indicates there should be about 10 amperes flowing when the switch is closed. The ammeter has a range from 0 to 10 amperes; however, we have used the 0 to 50 range just in case the flow happens to be more than 10 amperes, which could harm the meter on the 10-ampere range. We have connected the red or positive test lead to the common terminal of the meter because it's marked positive (+). The black or negative lead is then connected to the 50 ampere terminal of the meter. We know the ammeter must be connected in series with the circuit so we have connected the red lead to the positive side of the circuit and the black lead to the negative side of the circuit. In a later lesson, you will see how an ammeter is used to check the generator output or charging rate. In a generator output rate test, the current flow will be from the generator back to the battery. In order to read upscale the leads must be connected to the circuit in reverse of a load test. That would be red or positive lead to negative and black or negative lead to positive. Any load on the circuit would then be indicated to the left of zero or down scale. The charging rate from the generator would be indicated upscale.



h. Once you are connected correctly for a load test, complete the circuit by closing the switch. Current will then flow from the battery, through the load, through the ammeter to the switch, and back to the battery. As the current passes through the ammeter, the amount of current flow will be indicated on the upscale side of the ammeter.

i. The amperage capacity of an ammeter will depend on its construction. The ammeter used for the load test above can accept no more than 100 amperes through the meter. With the use of an external shunt, greater amounts of current can be measured. You will learn how a shunt is used later in this subcourse.

j. From what we have covered so far, you can see that the automotive electrical system can be compared with a water system. We have learned that both systems work under pressure and that the pressure can be measured. We also learned that the pressure causes a flow in the system when the system is in use. This flow can also be measured. The amount of flow in each system depends on the amount of pressure and how much resistance is in the particular circuit or system. In the simple water system, the size of pipes and the opening of the valve can both create resistance in the system. The waterflow will change, however, if the pressure is increased or the resistance is decreased. The resistance could be decreased by opening the valve more and increasing the size of pipes. The amount of resistance in an electrical circuit also depends on several factors. But, how do you know if the resistance in a circuit is correct? One way is to measure the voltage and amperage. If the voltage is correct but the amperage is not, you can safely assume the resistance is wrong. Let's find out how we can measure resistance by itself.

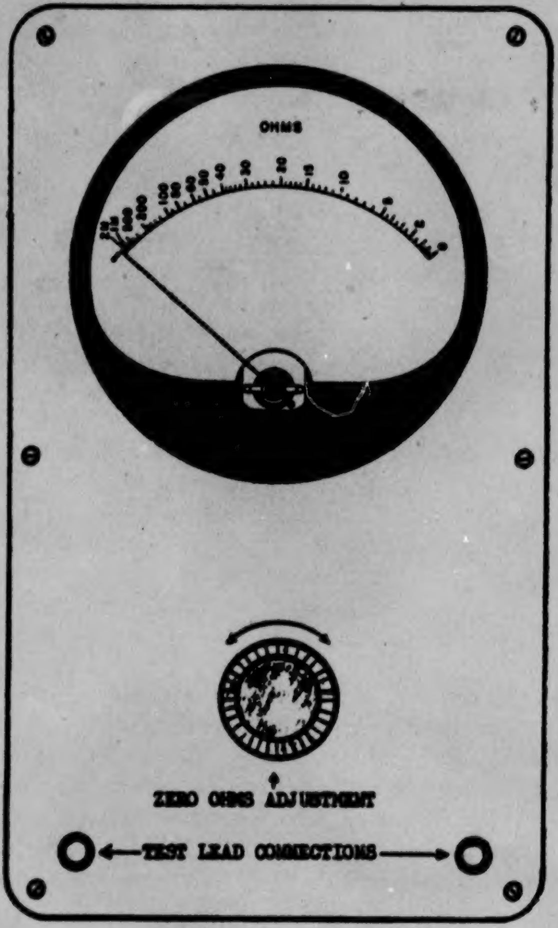
4. OHMMETERS. Anything moving meets resistance (opposition to movement). Remember what happens to the space capsule our astronauts are in when it returns to the ground after a trip in space? It gets so hot it has to have a heat shield to keep the astronauts from being burned to death. The heat is caused by the resistance of the air as the space capsule moves through it. The faster the capsule moves, the greater the resistance offered by the air. Resistance to motion always creates heat.

a. Resistance or the opposition to the movement of electricity in a wire also produces heat. Sometimes we want a lot of resistance in a wire. For example, the wires in the burners on an electric stove get red hot, and the wires in a light bulb get hot enough to glow and produce light. Other times we want as little resistance as possible in an electrical circuit, because the resistance causes heat, loss of voltage, and a reduction in the amount of of current that will flow.

b. The unit of measure for electrical resistance is called the ohm. The instrument used to measure the resistance in an electrical circuit is called an ohmmeter. Many things can happen in the electrical circuit that will change the amount of resistance in the circuit. Rust or corrosion at points where wires are joined together will cause an increase in the resistance. If the wires are not tightly joined together, there will be an increase in the resistance to the flow of electric current. Wires that have been partially cut are another cause of high resistance. Whatever the cause, when the resistance in a circuit is too high, the load unit in the circuit (such as a horn, radio, headlight, or starter) will not work right - if it works at all.

c. The ohmmeter may be constructed as a separate meter or, more often, as a part of a combination-type of meter known as a multimeter. Combination meters are sometimes called volt-ohm-amp meters. These meters vary in construction depending on the manufacturer. Let's find out what the simple ohmmeter looks like and how it is used.

d. Most simple ohmmeters have one scale. The scale is calibrated or has numbers from zero (0) to infinity. The symbol for infinity looks like a figure 8 lying on its side (∞). Infinity means more than the meter will measure. You should notice in the figure of the simple ohmmeter dial that the scale goes from 0 to 500 and then to 1M, 2M, and infinity. The 1M means 1,000 ohms and the 2M means 2,000 ohms.



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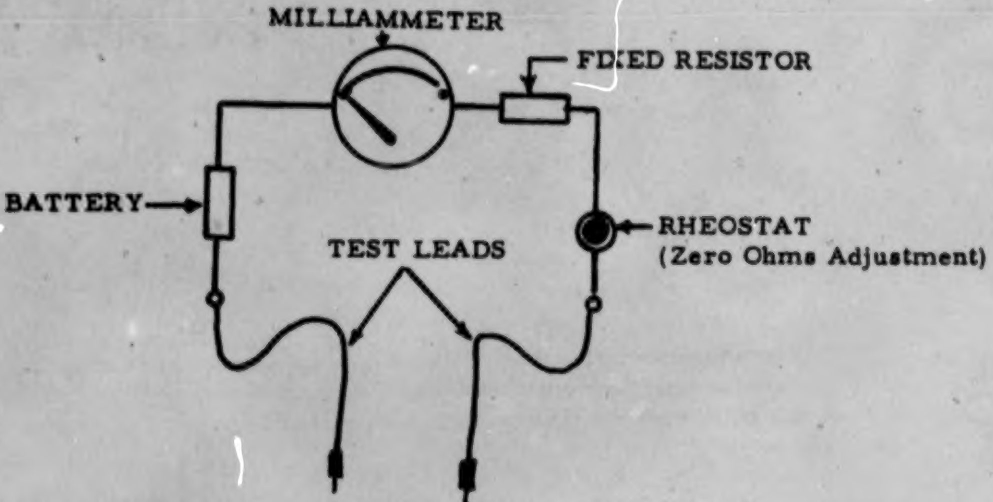
e. An ohmmeter is actually an ammeter that measures current flow in thousandths of amperes. This type of ammeter is referred to as a milliammeter. If you look at the accompanying illustration you can see what it takes to make up an ohmmeter. Most ohmmeters consist of the milliammeter, a battery, some form of current limiting resistance unit, and the case. In most ohmmeters, the resistance unit is actually two resistors. One is a fixed resistor and the other is a variable resistor or a rheostat as it is often called. The simple ohmmeter has two test leads connected to two terminals. You should notice how the test leads are connected to the basic circuit of an ohmmeter:



f. The ohmmeter has many uses. By measuring resistance, it can be used to locate shorted or open circuits and check circuit continuity (zero resistance). For example, consider a wire that is broken somewhere inside of a wiring harness. You can easily see each end of the wire where they are connected in the circuit, but the rest of the wire is hidden once it enters the harness. The ohmmeter can be used to check the continuity of the wire (see if it is broken).

g. Remove the ohmmeter test leads from the case and connect them to the two terminals on the ohmmeter. If the wire to be tested is in a vehicle, turn off all electricity in the vehicle's electrical system. THIS IS IMPORTANT. The ohmmeter has its own low-voltage battery and the meter will be burned out if higher voltage is allowed to enter it. The next step is to zero the ohmmeter. When the meter is not in use, the pointer or hand will be on the infinity mark. To zero the meter, touch the test lead ends together to complete a circuit. If the meter hand does not move to zero, turn the zero ohm adjustment knob until it does. This changes the resistance of the variable resistor. You will find as the battery of the meter ages that you will have to make additional adjustments with the zero ohms adjustment knob to make up for the weaker battery. If the hand will not come back to zero with the adjustment, the battery is too weak and must be replaced.

h. Once the ohmmeter is zeroed, connect one lead to each end of the wire to be tested. If the wire is not broken, the tested wire will complete the circuit through the ohmmeter and the indicating pointer or hand will move to zero. On the other hand, if the wire is broken the circuit will not be completed and the hand will not move. As you can see, the ohmmeter is connected in series with the circuit because the meter movement is actually an ammeter.

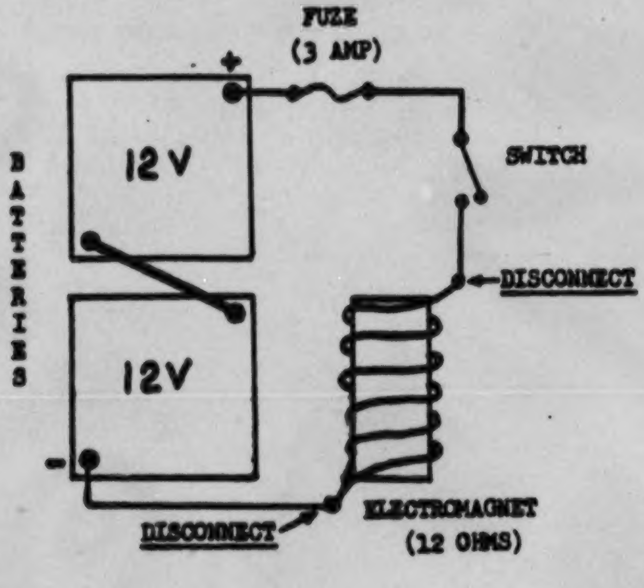
i. The ohmmeter is also valuable for testing the many types of switches. Suppose you have a small on-off switch that you think is not working, even though the lever from off to on and back to off seems to click normally. The switch has two electrical terminals. To test the switch with an ohmmeter, first zero the ohmmeter as explained above, then connect one test lead to each terminal of the switch. With the switch in the OFF position the ohmmeter hand should not move. Then move the switch lever to the ON position. The ohmmeter hand should move to zero.

j. Let's say when you tested the switch the ohmmeter hand remained on zero in both positions, ON and OFF. What does this tell you? Remember what makes the hand move to zero—a complete circuit through the ohmmeter and switch. This tells you the switch is not working properly, it does not break or open the circuit. On the other hand, if the ohmmeter indicated infinity in both ON and OFF positions, the circuit is not being closed. This means the switch is not making contact inside. You should now see how the ohmmeter can be used to locate open circuits due to a defective switch or a broken wire. You should also know how to test the action of a switch from off to on and back to off.

k. You can also use the ohmmeter to check for shorts or an unwanted grounding effect. Let's go back to that simple on-off switch and check it to see if it is grounded. As you learned in the previous lesson, the vehicle chassis acts as one wire or part of the circuit. If the switch is mounted in metal, the circuit through the switch must be insulated from the metal or the circuit will be grounded out. If the insulation fails, due to cracks, breaks, wear, etc, the contacts or terminals could touch the metal frame and ground out. The switch can be tested for grounding by connecting one ohmmeter test lead to the metal frame of the switch and the other to one terminal. The ohmmeter hand should not move if the switch is not grounded. Then change the switch position and look at the meter. Test both terminals in this manner. If the ohmmeter hand moves from infinity, the switch is grounded. You have found a complete circuit or continuity from a terminal through the switch metal frame. The switch must be replaced.

l. So far we haven't paid too much attention to the numbers or values on the ohmmeter scale. We have tested using infinity and zero, but how about the numbers in between these two. These numbers are used when you want to measure resistance. As a wheeled vehicle repairman you will not be removing or replacing many resistors; however, you will be working with many electrical components. Many of these components, when functioning properly, place resistance in an electrical circuit. Earlier in this lesson we learned that these components were called the load in a circuit. If the resistance of these components is other than the specified resistance the component and/or the electrical circuit will not function properly. Let's see how the ohmmeter is used to measure the resistance of the load. We will make up a circuit for a test.

m. Let's assume we have a circuit that is fuse protected. (Some circuits are circuit breaker protected.) The circuit includes a set of batteries, electromagnet, on-off switch, and a 3-ampere fuse. You can see a wiring schematic of the circuit in the accompanying illustration. For the purpose of this test we'll say the circuit blows the fuse each time a replacement fuse is installed and the switch is closed. The circuit has been checked and the wires are not grounded. The fuse is of the right amperage (3 amperes) for the circuit. The battery voltage is normal (24 volts). The fuse won't last long enough to make an amperage load test on the circuit. The only component in this circuit that creates any measurable resistance is the load—the electromagnet. According to the wiring schematic, the electromagnet should place 12 ohms of resistance on the circuit. Let's disconnect the electromagnet from the circuit as indicated in the illustration and measure the electromagnet's resistance. Don't forget to zero the ohmmeter first. Remember, the circuit to be tested is hooked in series with the ohmmeter.



n. For the purpose of this test let's say the ohmmeter hand indicates or shows 6 ohms of resistance. This is only half of the 12 ohms the electromagnet should have. The resistance is too low! Can this difference cause the 3-ampere fuse to blow? If you remember in the previous lesson you learned some laws about electricity. One law stated if the resistance increased in a circuit and the voltage remained the same, the current or amperage would decrease. In this case we have the opposite of this statement. The resistance decreased, the voltage remained the same, and, therefore, the amperage or current increased. The amperage is increased to more than 3 amperes and the fuse does just what it's suppose to do. It blows, opening the circuit. This protects the circuit from an overload that would otherwise damage the wiring and components.

o. How many amperes were actually flowing in the circuit above? You should remember in the previous lesson that you studied about the quantities of a circuit. You learned that the voltage is always equal to the amperage times the resistance. Let's see how this works out in the above circuit. Look at the accompanying figure as we work out the problems and you will find it's very easy. The circuit included a 24-volt set of batteries so the word "voltage" is replaced with 24. The electromagnet NORMALLY placed 12 ohms of resistance in the circuit so we replace the word "resistance" with 12. Now all we have to do is find what number multiplied by 12 (resistance) equals 24 (voltage). This is easy—2 times 12 equals 24 so we replace the word "amperage" with 2. Now we know that a circuit with 24 volts pressure and a 12-ohm load will cause 2 amperes to flow in the circuit. This is the normal amperage flow in this circuit. The circuit was protected with a 3-ampere fuse and all was well until the load (electromagnet) became defective and started placing only 6 ohms on the circuit. Let's use the same formula and find out how and why the fuse blew.

**VOLTAGE = AMPERAGE X RESISTANCE**

24 = ? X 12

$$24 = \textcircled{2} \times 12$$

p. The voltage remained the same so we start out with 24 for voltage. We know the resistance is 6 so we replace the word "resistance" with 6. What number times 6 equals 24? You've got it - 4, so the current or amperage flowing in this defective circuit is 4 amperes. The circuit was allowed 1 ampere over its normal ampere load by using a 3-ampere fuse, but this is a 2-ampere overload and the fuse will burn through and break the circuit. Try this formula (voltage equals the amperage times the resistance) using other numbers or values. For example, change the voltage to 12 and the resistance to 4 ohms. See if you can find the amperage flowing in the circuit.

$$\text{VOLTAGE} = \text{AMPERAGE} \times \text{RESISTANCE}$$

$$24 = ? \times 6$$

$$24 = \boxed{4} \times 6$$

$$\boxed{\begin{array}{r} 6 \\ \times 4 \\ \hline 24 \end{array}}$$

q. You should now have a good idea how the ohmmeter can help you in testing and locating electrical system troubles. As indicated before, the ohmmeter you will probably use will be part of a multimeter which is covered later in this lesson. Remember, the ohmmeter is actually an ammeter and is therefore connected in series with a circuit. ALWAYS disconnect the vehicle battery or batteries from the circuit BEFORE connecting the ohmmeter to the circuit. You can use the ohmmeter to measure resistance, locate open circuits (broken wires), and shorts (touching wires). You can also check the operation of switches and locate grounds in a circuit. The ohmmeter is a valuable test meter - take care of it.

r. So far you have learned about the voltmeter, ammeter, and ohmmeter as separate test meters or instruments. It's more practical to combine some of these meters into one unit. You will be using two instruments of this type: the low-voltage circuit tester and the multimeter. Let's see what these combination meters consist of and how they are used.

Note. - Complete exercises number 41 through 48 before continuing to section II.

41. What test meter measures electrical pressure?

    a. Voltmeter
    b. Ammeter
    c. Ohmmeter

42. To help prevent shocks or burns when testing automotive electrical circuits, the repairman should

    a. leave the battery disconnected.
    b. ground the generator.
    c. remove jewelry and watches.

43. How is a voltmeter connected into a circuit?

    a. Series
    b. Parallel
    c. Series-parallel

44. Waterflow is measured in gallons. Electrical flow is measured in

    a. volts.
    b. ohms.
    c. amperes.

45. Which malfunction could cause the normal current flow in a circuit to increase?

    a. Undersized electrical conductor
    b. Dirty switch contacts
    c. Shorted relay winding

46. Which meter is equipped with its own battery?

    a. Voltmeter
    b. Ammeter
    c. Ohmmeter

47. The "ohms adjust" knob on the ohmmeter is turned back and forth to zero the meter while the ends of the ohmmeter leads are

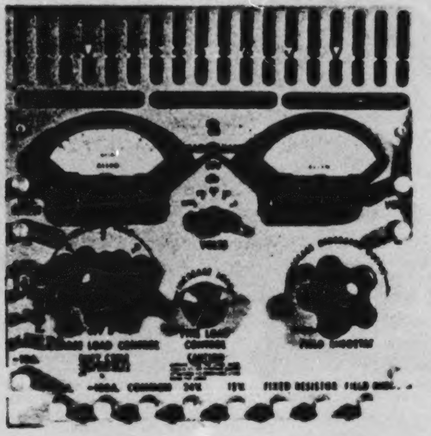
    a. connected to the circuit being tested.
    b. attached to the vehicle's batteries.
    c. clipped together.

48. How many amperes should be measured in a circuit with a 12-volt battery and a total of 4 ohms of resistance?

    a. 3
    b. 8
    c. 48

## SECTION II. LOW-VOLTAGE CIRCUIT TESTERS

5. INTRODUCTION. The military low-voltage circuit tester is a heavy-duty test instrument. When you open the case you will see two test meters that you are already familiar with: the ammeter and voltmeter. A closer look will show that there are some connections and controls not found on the simple ammeter and voltmeter. Although some repairmen shy away from the low-voltage circuit tester, it is really quite simple to use. Further, once you learn what each connection and control is used for, the LVCT will make your troubleshooting problems a lot easier to solve. The low-voltage circuit tester is quite often called the LVCT, which is nothing more than the first letter of each word in its name.



6. CONSTRUCTION. Once you are assigned to a unit that is authorized an LVCT, you should learn to use it as soon as possible. If your unit is issued a second LVCT that doesn't look anything like the first, don't send it back. At present the Army uses several different models of LVCT's. There is only one Federal stock number (FSN) for all of these. This means your unit may order a low-voltage circuit tester under FSN 4910-092-9136 and receive any one of three different testers. All of the LVCT's include one ammeter and one voltmeter. However, the controls and connections may vary between models.

a. Low-voltage circuit testers vary depending on the manufacturer. The LVCT in your unit could be made by any one of the following firms: Auto Test Inc model 10308, Atomic Engineering model TV100, Austin Continental Industries model 1060/A, Electro Mechanisms, Inc, model 1060, Ram Meter Inc, model 62F151, Allen Electric and Equipment Company, model 30-92, and Futrenics Industries Inc model 225-01. If you tried to learn each of these LVCT's from one lesson you could be confused. However, if you learn how to use one you should easily learn how to use the others by following their instructions. Let's see what the Allen model 30-92, low-voltage circuit tester, looks like and how it is used.

b. The Allen model 30-92 LVCT is a portable (can be hand carried) test instrument. It is used for testing low voltage, direct current, electrical circuits on automotive-type vehicles. The unit includes a voltmeter and ammeter, to measure voltage and amperage, and a load bank that is an adjustable resistance unit. The load bank is used when current tests of values up to 100 amperes on a 24-volt circuit are made. You will learn how the load bank is used in later lessons.

Note. - Refer to fold out illustration number 1 in the back of this pamphlet

7. COMPONENT LOCATION AND PURPOSE. The illustration shows the LVCT with the cover removed. Let's look at the various controls, meters, and connections on the face of the instrument.

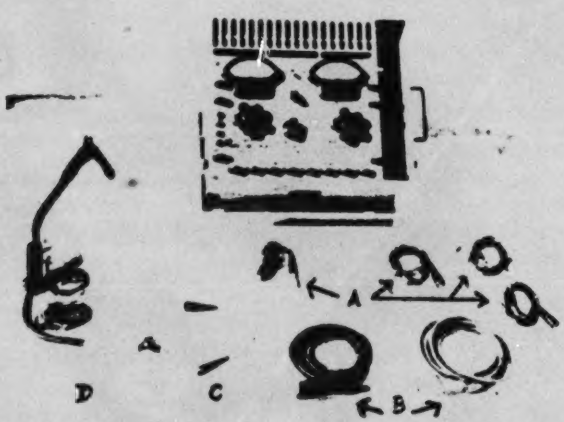
a. We will start with the ammeter. Notice that it's of the same type used in the simple ammeter in this lesson, and is located on the upper left side of the tester. It has ranges from 0 to 500 amperes to the right of the zero, and from 0 to 150 amperes to the left of the zero. This type range or scale is known as a minus 150-ampere to plus 500-ampere range. The minus figures are used to measure reverse current without reversing the meter leads. As indicated earlier, you will learn how to use this side of the zero in a later lesson.

b. The coarse load control is located directly below the ammeter. This is part of the load bank controls. The control includes 8 positions plus an OFF position. During a 24-volt load operation, each position adds 12.5 amperes of load when the knob is turned to the right. If the tester is being used for a 12-volt load operation, each position from 2 to 8 adds 6.5 amperes of load. Position 1 of the coarse load control has no control during the 12-volt load operation. The load bank also includes a fine load control located to the right of the coarse load control. This is used if you want an amperage load between the 12.5-ampere positions for 24 volts. It can also be used for the 12-volt load operation.

c. The field rheostat control, located in the lower right of the tester, is a variable resistor. It is used, as indicated, to change the generator output which will be covered in a later lesson. This control should be left in the open position when the field rheostat is not in use.

d. The voltmeter in the upper right of the tester is of the same type shown earlier in the lesson. It has two scales, four rows of numbers, and four ranges that can measure from 0 to 50 volts. The 0 to 10 scale is also used as an accurate 0 to 1 volt scale or range. The voltmeter has a range selector switch located to its lower left. The switch to the left of the voltmeter dial is used to turn the load bank on or off and should be left in the "off" position when not in use.

e. The compartment along the right-hand side of the tester is used to store test leads. There are seven separate leads and an external shunt. The leads consist of four 16-gage (light) leads (three black and one red (A)), two 6-gage (heavy) leads (one black and one red (B)), and one black jumper lead (C). The 16-gage leads are used to connect the voltmeter to a circuit and to connect the field rheostat to a generating circuit. The two 6-gage leads are used to connect the adjustable load bank, ammeter and the fixed resistor to a circuit. The black jumper lead can be used anywhere it is needed in a circuit with low amperage. The external shunt (D) consists of two large and two small leads. It is used when measuring loads from minus 150 amperes to plus 500 amperes.



f. The area above the ammeter and voltmeter has long slots cut in the metal. These slots allow air to circulate through the LVCT for cooling purposes. It is very important when the meter is in use that they are not covered in any way because the unit will overheat.

g. Many terminals or connections are located around three front sides of the LVCT. We will start with the terminals to the left of the ammeter. The first two terminals are used to connect the external shunt to the LVCT. The terminals are polarity marked (+) and (-). The small red lead of the shunt is connected to the positive (+) terminal and the black lead to the negative (-) terminal. While we are at it, let's see how these terminals work. The part on the top of the terminal is the head of a screw. It is knurled and rough so it will not slip in your fingers. The screw is threaded into a long smooth nut. The nut has a hole bored at right angles to the threaded screwhole. The test lead has a long pin on the meter end which fits into this hole. To make a connection, loosen the knurled screwhead by hand (THUMB AND FINGER). Unscrew the knurled screw until the test lead pin will slide through the hole. Then turn the knurled screw in until it is snug on the pin. DO NOT TIGHTEN OTHER THAN BY HAND. All of the test lead connections are connected in this manner.

h. Just below the external shunt connections you will see two straps. Each strap can be connected to two terminals. These straps are called links because they are a link of a circuit when they are connected. We could say they are actually a switch because they can be used to open or close a circuit. The upper link is used with the external shunt. Notice in the foldout of the LVCT that there are instructions to open the link only when using the external shunt. The link will therefore be closed for all other tests. The link can be opened by first loosening both knurled nuts on top of the link; then swing the link away from one terminal and tighten the knurled nuts. Only one end of the link is slotted. The lower link in the foldout is shown in the open position. Be careful that the upper link does not swing around enough to touch the upper terminal of the lower link. The lower link always is left open unless the LVCT load bank is used to test a 12-volt circuit. Then it is closed.

i. The next four terminals are used with the ammeter. The 6-gage test leads are connected to these terminals. Three of the terminals are marked negative (-) and each of the three match one of the scales or ranges on the ammeter. The fourth terminal is marked COMMON and is therefore the positive (+) connection for the three ranges. For example, if you wish to measure a current flow of 20 to 30 amperes, you would connect the leads to the LVCT as follows: the red lead positive to the common terminal and the black lead to the -50A (ampere) terminal. The other ends of the leads would be connected in series with the circuit to be tested.

j. The next two terminals, located below the fine load control, are marked 24V (volt) and 12V respectively. These terminals are used with the COMMON terminal when placing a load on a circuit with the load bank. The 6-gage test leads are also used with these terminals. This is because heavy amperage (up to 100 amperes on 24-volt circuits) can be made to flow through these terminals. You will see in a later lesson that the black lead is connected to the common terminal when using the load bank. The red lead is then connected to the 12- or 24-volt terminal, depending on which voltage circuit is being tested.

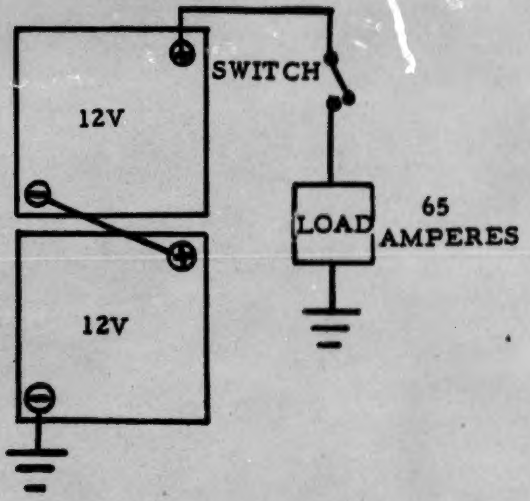
k. The next two terminals are used to connect a fixed resistor to a circuit. The resistor is located in the LVCT and is rated at 0.25 or 1/4 ohm of resistance. It is used to test some types of voltage regulators.

l. The next two terminals are marked FIELD RHEOSTAT. These terminals are used to connect the adjustable resistor to a circuit. The field rheostat is used to change the strength of the electromagnet in generators, therefore changing the generator output. It can also be used to add a varied amount of resistance in other electrical circuits, if desired.

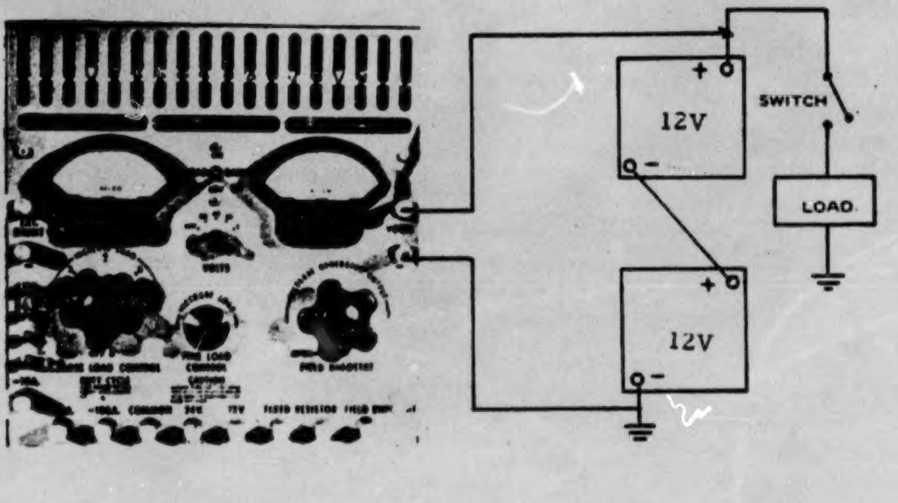
m. The last two connections or terminals are marked VOLTS. One terminal is marked positive and the other is marked negative. These terminals are the connections for the voltmeter and are located right beside it. The 16-gage color coded test leads (red/black) are used with these voltmeter terminals. The voltage range selector between the two meters connects the terminals to the proper range on the voltmeter.

n. The off-on switch between the two meters is used to turn the load bank on and off. It is always left in the off position except when the load bank is in use. Now that we have a good idea where each component of the LVCT is located and what they are used for, let's apply the knowledge we have gained and see if we can hook up the LVCT. We will use the simple circuits that you are already familiar with.

8. APPLICATION. Let's say we want to test the voltage in the circuit just like the one in the accompanying illustration. We will make two tests. The first will determine what the battery voltage is with the switch open. The second test will be made with the switch closed. This way we can see how much the voltage drops when the load is connected to the battery. The connections for both tests are the same. Make the connections in the following manner.



a. First, make sure the voltage selector switch of the LVCT is in the OFF position. Next, connect the 16-gage leads to the voltage testing terminals of the voltmeter. Make sure you have the polarity right. Then connect the test leads to the circuit to be tested. Remember, across or parallel with the circuit and keep the polarity right. Once you are connected, turn the voltage selector switch to 50 and read the 0 to 50-volt range. Remember or write down the voltage reading. Then close the switch in the circuit and read the voltage with the load connected. The difference between the two readings is the amount of voltage drop when the circuit is completed and the load is connected to the battery. When you finish reading the voltmeter open the switch of the circuit, turn the voltage selector switch to off, and remove the test leads. You can see that the voltage test of this circuit was easy. To make an amperage test on the same circuit, proceed as outlined in the next paragraph.



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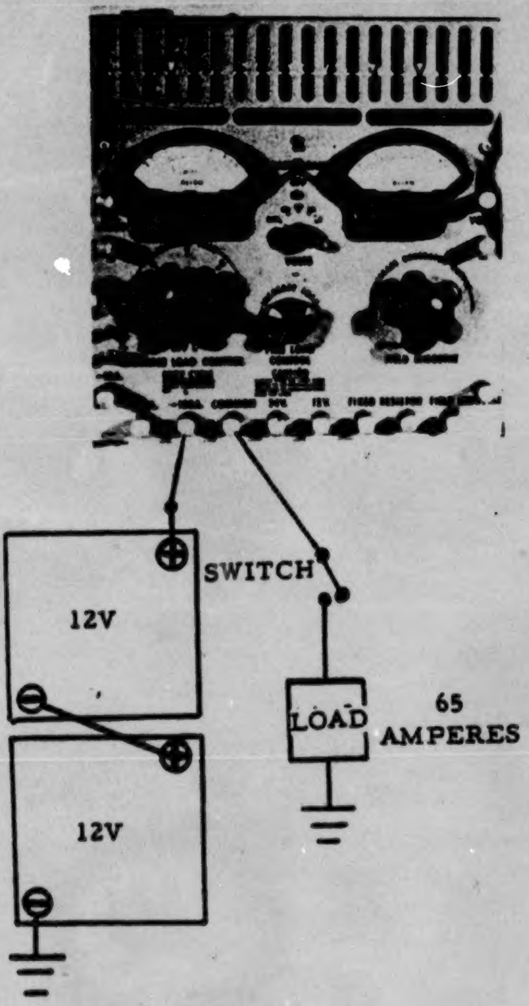
**Foldout illustration No 1. Allen model 30-92 low voltage circuit tester.**

b. Make sure the switch is open in the circuit to prevent arcing when the test leads are connected. Notice the load should cause 65 amperes to flow in the circuit. Select the correct amperage range terminals on the LVCT, then connect the 6-gage positive test lead to the common terminal and the black 6-gage load to the 100 ampere (-100A) terminal. Make sure the 12-volt link is in the open position. Then break the circuit at a convenient place and connect the test leads. Close the switch in the circuit and the ammeter should indicate the amperage flowing in the circuit. When finished, OPEN THE SWITCH. Never try to disconnect a test lead while the circuit is loaded. Now remove all test leads and place them in the storage compartment in the LVCT, reconnect the circuit, and you have finished.



c. As you can see it's easy to use the LVCT for simple tests like these. During later lessons in this subcourse, you will learn how to use the LVCT to test such things as starter amperage flow and generator output. During this lesson, we have discussed only one type of LVCT to help you learn what the tester is and what it's used for. Each LVCT has an instruction booklet. If you have any questions on how to use the tester, always refer to the instruction booklet.

Note. - Complete exercises number 49 through 56 before continuing to section III.

49. Although the Army uses several makes and models of the LVCT, all of them

    a. have the same maintenance allocation chart (MAC).
    b. pertain to the same technical manual (TM).
    c. can be ordered by the same Federal stock number (FSN).

50. Which meter has a row of minus (-) numbers on the left side of the zero?

    a. Voltmeter
    b. Ammeter
    c. Ohmmeter

51. How many rows of numbers are found on the face of the voltmeter used on the model 30-92 low-voltage circuit tester?

    a. 3
    b. 4
    c. 5

52. Which scale on the LVCT voltmeter should be used to accurately measure up to 1 volt?

    a. 0 - 10
    b. 0 - 20
    c. 0 - 50

53. From what scale on the ammeter of an LVCT should the reading be taken when using the external shunt?

    a. 500-ampere scale
    b. 100-ampere scale and multiply by 5
    c. 50-ampere scale and multiply by 10

54. What kind of leads are found on the external shunt used with the LVCT?

   a. 2 large and 2 small leads
   b. 4 large leads
   c. 4 small leads

55. What is the voltage range on the voltmeter used on the LVCT?

   a. Zero to 24 volts
   b. Zero to 50 volts
   c. Zero to 80 volts

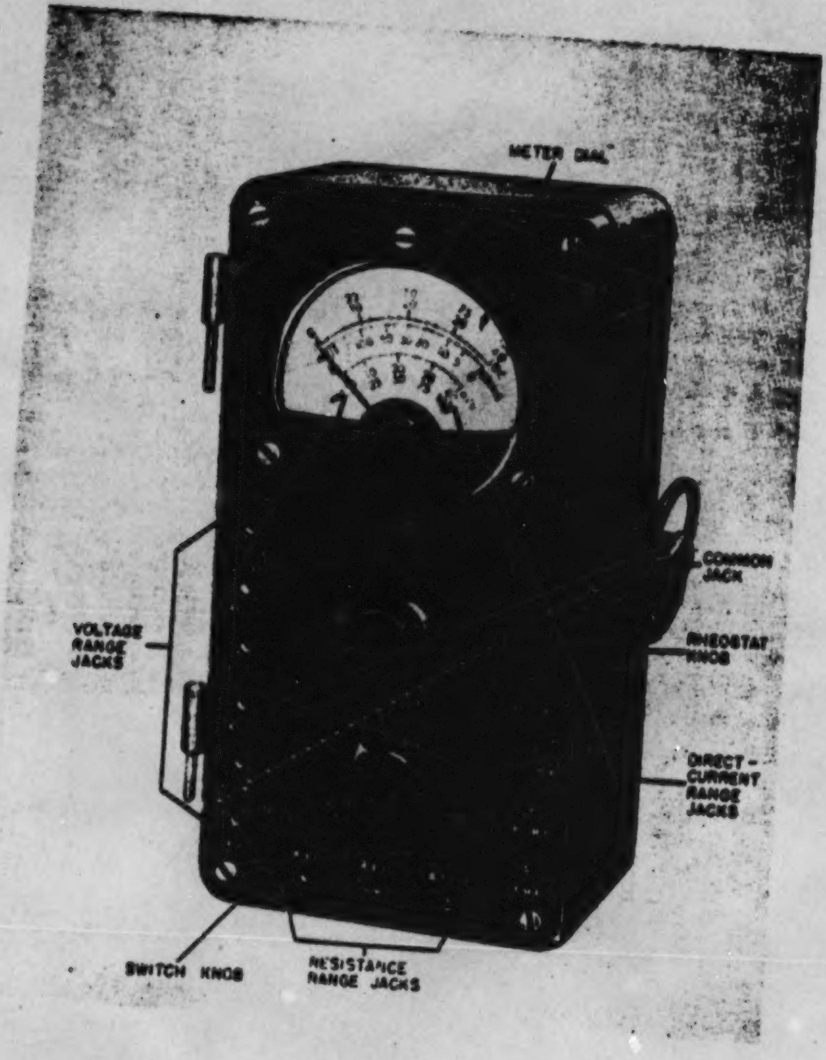
56. Which statement is TRUE in regard to connecting the LVCT to a circuit?

   a. Voltmeter test leads are connected to a circuit in reverse polarity to make a voltage drop test
   b. The six gage test leads are used when making an amperage test on a circuit
   c. The red test lead is connected to the terminal marked COMMON when measuring voltage

## SECTION III. MULTIMETERS

9. INTRODUCTION. We learned earlier in this lesson that most ohmmeters that you will use will be part of a multimeter. You are probably thinking that the LVCT had more than one meter - why isn't it called a multimeter? Well, it could be, however it measures only DC voltage and amperage and is therefore called a low-voltage circuit tester. The multimeter can be used to measure AC and DC voltage, amperage, and resistance. You will normally use the multimeter as an ohmmeter.

10. **CONSTRUCTION.** Notice in the illustration that the first difference between the multimeter and *LVCT* is that the multimeter has only one meter dial. The one dial has scales for indicating values *for* each of the tests that the meter can make.


METER DIAL
COMMON JACK
VOLTAGE RANGE JACKS
RHEOSTAT KNOB
DIRECT-CURRENT RANGE JACKS
SWITCH KNOB
RESISTANCE RANGE JACKS

a. The jacks for the various tests are located around the bottom edges of the meter. Notice the common jack on the top right. It is used for the negative lead for all tests. The positive lead would then be placed in the appropriate jack for the test being made. In some multimeters a range selector switch is used in place of separate jacks for each range. When this happens the meter will have a common positive and negative jack.

b. The rheostat knob is used to zero adjust the meter for resistance tests. If you recall, we stated earlier that when making resistance tests, the leads are placed in the proper jacks of the meter and the test probes of the leads are touched together. If the ohmmeter scale does not indicate zero, it can be corrected by turning the zero adjust knob.

c. The switch knob is used to position components of the meter in the proper circuit for the test to be made. This meter has three positions: one each for testing resistance, AC voltage, and DC voltage and current.

d. The meter dial has three scales:

(1) The top scale is for DC measurements. It can be used for either voltage or current. Notice that the numbers are shown as 0-40 and 0-100. The voltage range jacks on the left side of the meter are for 4V, 10V, 40V, 100V, 400V, and 1,000V. The 0-40 scale is used for jacks 4V, 40V, and 400V. For the 4V range consider the scale as going from 0-4, just leave the zero off each number. For the 400V range simply add another zero to the numbers on the scale. The 10V, 100V, and 1,000V ranges would be read on the 0-100-volt scale the same way.

(2) The middle scale is the ohms scale. Remember, the scale is read from right to left. In other words, if there is no resistance in a circuit, the pointer will go all the way to the right or to 0 ohms. As resistance increases, the pointer will stay farther to the left. Notice, that on this meter, the resistance ranges are RX1, RX10, and RX100. Depending on which range is being used, you will either accept the number shown or add one zero for RX10 and two zeros for RX100.

(3) The bottom scale is for AC voltages. The 0-40 and 0-100 scales are used the same as those for DC.

e. The thing you must remember is that all meter scales will not be the same. You must use each meter in accordance with the way it is designed.

11. MEASURING RESISTANCE. When performing a resistance test, BE SURE THAT THERE IS NO POWER APPLIED TO THE CIRCUIT BEING TESTED. Any power other than that supplied by the ohmmeter will destroy the meter. In our discussion of how to perform a resistance test, let's consider a circuit that could very possibly be one you might have to work on.

Note. - Refer to fold out illustration number 2 in the back of this pamphlet.

a. The first thing you will notice is that we have a different type of multimeter illustrated here.

(1) First, look at the dial—the ohms scale is on the top.

(2) Second, look at the jacks—the ones we will use for a resistance test are on the bottom left corner.

(3) Third, notice the range selector in the middle—on this meter you simply position the selector to the range desired for the particular test you are making.

b. Now let's look at the circuit we are going to test. It is a simple schematic of the components of a typical vehicle starter circuit required for the starter circuit. For our situation in this test we will say that the batteries are probably charged. However, when the starter switch is closed, the starter motor will not run. This indicates that the relay in the starter circuit may not be operating. We want to test the resistance of the relay.

c. To set up the multimeter for the test proceed as follows:

(1) Connect the phone tip ends of the meter leads to the common and plus (+) jacks.

(2) Turn the switch knob to DC.

(3) Turn the range selector to RX1.

(4) Touch the test lead probes together and adjust the zero knob until the meter needle points to zero on the ohms scale.

d. Once the meter is zeroed, remove the battery ground cable and disconnect the relay at either point h or i and connect the test leads to the two leads or connections of the electromagnet winding. Watch the meter hand; if it moves toward zero and stops, read the indication. Let's say it stops on 12. This would be 12 ohms of resistance. If the hand moves to zero when the test leads are connected to the winding, the circuit does not have enough resistance to be measured. This does tell us that the circuit through the electromagnet winding has continuity. The fact that it has little or no resistance indicates the winding must be shorted.

e. If the hand does not move when the leads are connected to the electromagnet winding, it is possible the winding has too much resistance to be measured on the RX1 scale. Try the RX100 scale next. If the hand still stays on infinity or doesn't move, try the RX10,000 scale. Remember to zero the meter for each scale. This not only calibrates the meter but also shows you the meter is working. If the hand does not move from inifinity on all three positions, you know the winding has too much resistance to be measured. It probably has a wire broken or is burned out.

f. If the winding does not have enough resistance it will overload the circuit. For example, let's say the winding should have 12 ohms of resistance but only measures 3 ohms of resistance. We remember from an earlier paragraph that when the resistance comes down and the voltage stays the same, the current goes up. We learned that voltage always equals the current times the resistance so this also proves the current (amperes) must go up in this case. Let's say in this circuit the voltage is 12 and the winding resistance should be 12 ohms. If we divide the resistance (12 ohms) into the voltage (12 volts) we find it goes 1 time or 1 ampere. If the resistance only measured 3 ohms, we divide the 3 ohms into 12 volts to get the current flow. This would be 3 into 12 equals 4. This means the amperage is up from 1 ampere to 4 amperes. The circuit should be made to carry the 1 ampere safely; however the 4 amperes will overload the circuit. Most circuits are protected with some type of a safety device. It could be a circuit breaker or a fuse. In case of an overload the circuit breaker or fuse opens the circuit to protect the wiring and other electrical components.

g. As you gain experience in automotive electrical system repair, you will learn the approximate resistance of each component. For example, you will learn that if the circuit is connected with light wires (18 gage or smaller) the current flow is going to be low. By dividing the approximate current flow (amperes) into the voltage you will get some idea what the resistance should be. You should always check the specifications for a system or component to get the exact amount. You should be able to find either the current or resistance for most components in the technical manual.

h. You can check continuity with this meter just as you did with the separate ohmmeter. Use the RX1 position and zero the meter before you connect it to the circuit. Like the ohmmeter, if the hand moves to zero when the leads are connected to a wire or component it has continuity. If the hand doesn't move from infinity it does not have continuity. It has an open circuit or excessive resistance. If the hand stops between the infinity mark and zero, there is a readable resistance in the circuit. This resistance could be normal if there is a load-type component in the circuit being measured. If there is no load component in the circuit, there could be a bad connection somewhere in the circuit. The continuity test will generally show this type of defect. If the continuity test on a circuit with a switch indicates resistance, the switch contacts could be dirty. This is one example of a malfunction causing resistance in a circuit. As you use the multimeter to check continuity you will learn how it will help you in locating loose connections, broken wires, dirty contacts, and other malfunctions. Once you finish using an ohmmeter, turn the range selector to any position other than a resistance position. This will prevent discharging the meter battery in case the test leads accidently touch each other.

12. MEASURING DC VOLTAGE. You can also use a multimeter to measure DC voltage. The meter in the foldout picture has more than one range on the DC scale. Its ranges cover the low voltage of a military wheeled vehicle very well. For example, one range is from 0 to 50 volts DC. This places the 24-volt system of most combat vehicles close to the center of the dial. Let's see how this particular meter is set up and connected to a circuit to measure DC voltage.

a. Let's say you want to measure the voltage across the two batteries that are connected in series in the foldout illustration. The two batteries should produce 24 volts connected in this manner. To use this multimeter to measure the voltage, turn the function selector switch to the DC position. Then turn the range selector switch to the 50V (volt) position on the left of the control, and connect the test leads to the same jacks used for the resistance test. These jacks are on the lower left of the control panel. Connect the test leads to the batteries. The red lead connects to the positive post at D, and the black lead to the negative post at A. The hand should stop on 24 volts if the batteries are full charged.

b. If you want to check a voltage of about 5 volts, it would be much better to use the 0-10 volt range as the meter would be indicating in the center of its range. Always use a range in which the measurement is indicated as near to the center as possible.

c. As you can see, the multimeter can be a valuable test instrument for the wheeled vehicle repairman. You can use it to locate shorts, broken circuits, and measure DC voltage as well as other tests. Remember when you use the multimeter as an ohmmeter, make sure the circuit to be tested has no voltage in it. Turn the voltage OFF. Otherwise, the meter can be damaged beyond repair. You will not learn how to use the ammeter section of the multimeter in this lesson as it is of very little value to you as a wheeled vehicle repairman.

Note. - Complete exercises number 57 through 60 before continuing to section IV.

57. The ohmmeter used most in automotive work in the Army is part of a unit called the

a. wattmeter.
b. multimeter.
c. low-voltage circuit tester.

58. What is indicated if the pointer on an ohmmeter stays all of the way to the left when checking a wire conductor?

a. Weak vehicle batteries
b. Circuit is open
c. Leads are reversed

59. How many ohms are being measured on a multiscale ohmmeter if the range selector is on the RX100 position and the hand indicates 35?

a. 35
b. 350
c. 3, 500

60. Which test can be made with the multimeter that can also be made with the LVCT?

a. AC voltage
b. DC voltage
c. Resistance

## SECTION IV. CONCLUSION

13. **SUMMARY.** In this lesson we have discussed how the automotive electrical system could be tested in the same manner that a water system is tested. We learned that the pressure in an electrical system is called voltage and is measured with a voltmeter. The flow in an electrical system is called current and is measured with an ammeter. We know that resistance in a circuit can be measured with an ohmmeter. We saw that the voltmeter and ammeter may be found as separate meters or as a part of a combination meter. A good example of this meter is the low-voltage circuit tester. The low-voltage circuit tester or LVCT contains many connections and controls to connect and test many types of circuits. The ohmmeter, we learned, is often part of a multimeter which can also be used to measure voltage and amperage. We know that an ammeter is always connected in series with a circuit, whereas a voltmeter is connected in parallel with a circuit. If we use an ohmmeter to check a circuit, WE MUST turn off all voltage in the circuit before the ohmmeter is connected.

14. **PRACTICE TASK LIST DIRECTIONS.** Appendix A contains a list of tasks associated with the principles and use of electrical testing equipment. They are representative of the tasks you will be required to perform as a wheeled vehicle repairman. Perform all of the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

## APPENDIX A

## PRACTICE TASK LIST

**Practice Objective.** After practicing the following tasks you will be able to:

1. Locate the types of electrical test equipment in your organization.
2. Understand how to connect and use your organizational test equipment.
3. Measure the voltage of a battery.
4. Check the continuity in a length of wire.
5. Measure the resistance of an electrical component.
6. Test the operation of a switch with a multimeter.
7. Connect the LVCT to measure the current flow in a circuit.

**Tasks.**

1. Look at the electrical equipment issued to your organization. See if you can identify the models of low-voltage circuit testers. Look at the connections, meters, and controls of each instrument.

2. Remove and study the instructions for each tester. Locate each control, meter, and connection as you study the instructions.

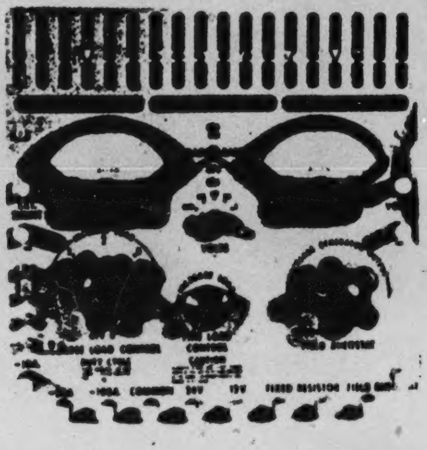
3. Set up an LVCT and multimeter and test the voltage in a flashlight battery. Make sure you connect the leads correctly.

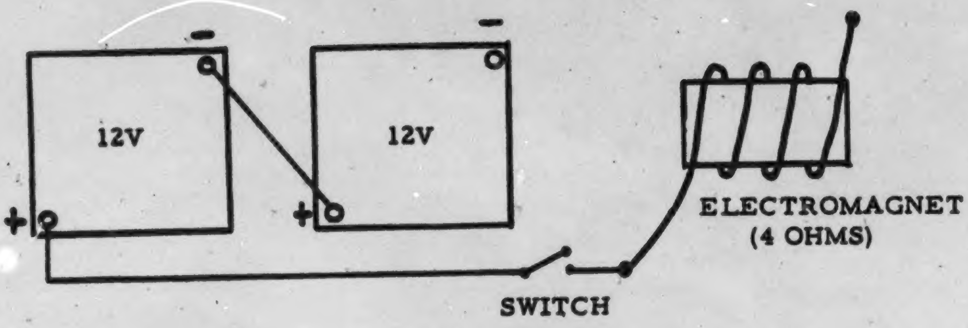
4. Check the continuity of a length of insulated wire. Make sure you use the correct resistance range.

5. Determine the resistance in a small automotive light bulb, such as a taillight bulb or an instrument bulb.

6. Test the operation of a simple on-off switch with the multimeter using the ohmmeter section. As the switch is opened and closed, the meter should move from infinity to continuity.

7. Complete the following circuit and connect the LVCT to the circuit to measure the current flow by drawing lines to and from the LVCT, battery, and the electromagnet. Make sure you use the right range on the LVCT ammeter.

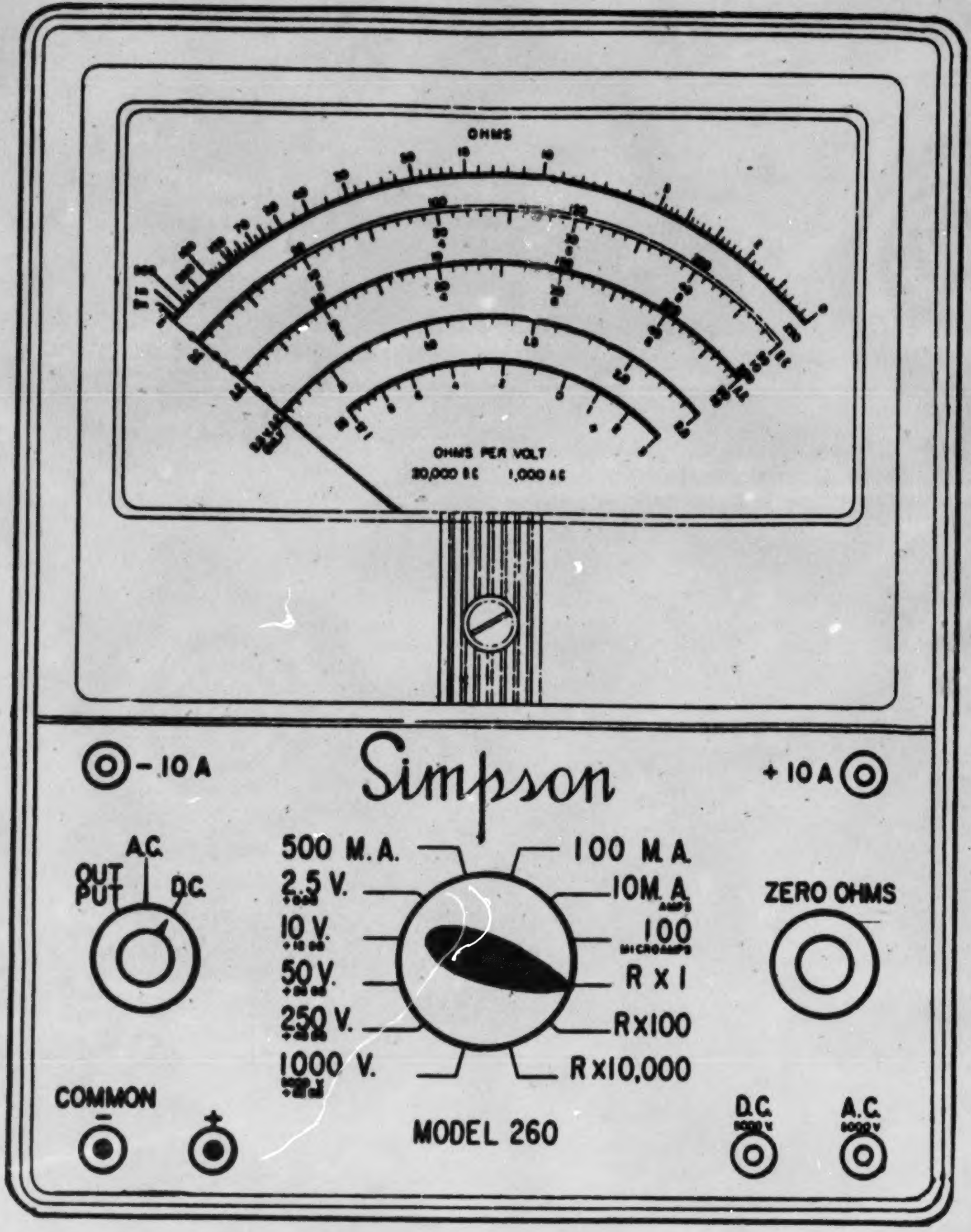


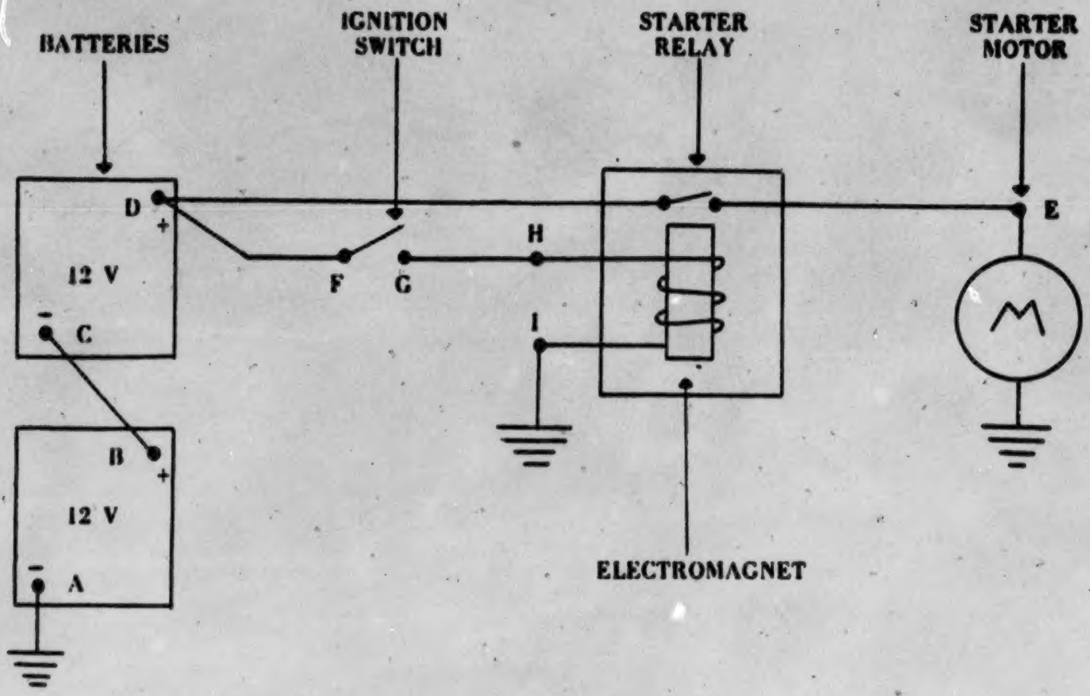


## APPENDIX B

## REFERENCES

| | | |
|---|---|---|
| TM 9-4910-456-14 | Test Set, Generator and Voltage Regulator, 12- and 24-Volt Systems | Oct 71 |


OHMS
OHMS PER VOLT
20,000 DC
1,000 AC
Simpson
-10A
+10A
A.C.
OUT
PUT
D.C.
500 M.A.
2.5 V.
10 V.
50 V.
250 V.
1000 V.
100 M.A.
10M.A.
AMPS
100
MICROAMPS
R x 1
R x100
R x10,000
ZERO OHMS
COMMON
−
+
MODEL 260
D.C.
5000V
A.C.
5000V

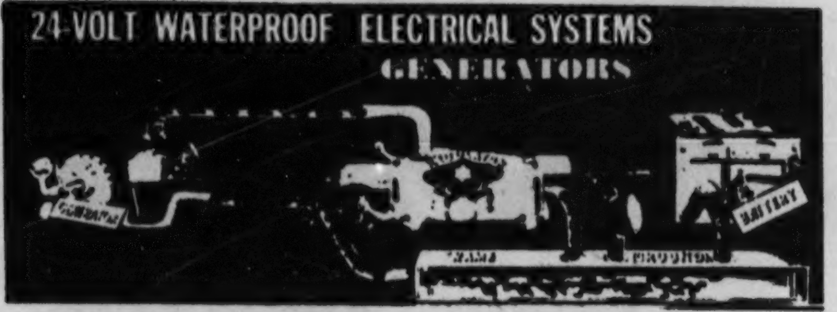

BATTERIES
IGNITION SWITCH
STARTER RELAY
STARTER MOTOR
D
+
12 V
−
C
B
+
12 V
−
A
F
G
H
I
E
ELECTROMAGNET

Foldout illustration No 2. Selector switch type of multimeter.

## ENLISTED MOS

## CORRESPONDENCE/OJT COURSE

# ORDNANCE SUBCOURSE 63B203


24-VOLT WATERPROOF ELECTRICAL SYSTEMS
GENERATORS

# LESSON 4
# GENERATING SYSTEMS

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

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# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

| | |
|---|---|
| Ordnance Subcourse 63B203 | Wheeled Vehicle Electrical Systems |
| Lesson 4 | Generating Systems |
| Credit Hours | Four |
| Lesson Objectives | After studying this lesson you will be able to:<br>1. Describe the construction and operation of a DC generator.<br>2. Explain how a DC generator output is controlled.<br>3. Describe the procedures for inspecting and testing a DC charging system.<br>4. Explain the procedures for removing and replacing components of a DC charging system.<br>5. Describe the construction and operation of an alternator.<br>6. Explain how an alternator output is controlled. |

7. Describe the procedures for inspecting and testing the components of an AC charging system.

8. Describe procedures for removing and replacing components of an AC charging system.

Study Assignment . . . . . . . . . . . Study the text carefully. It will provide you with the knowledge you will need to understand and maintain the generating systems of wheeled vehicles. It covers the construction and operation of charging system components and the procedures for inspecting, testing, removing, and replacing components of the charging system.

Materials Required . . . . . . . . . . All students: Exercise response list and answer sheet. Correspondence/OJT option students. See appendix A.

Suggestions . . . . . . . . . . . . . . . Study the illustrations and foldouts carefully along with the text so you will better understand the testing and maintenance of the generating systems.

## STUDY TEXT

### SECTION I. DC GENERATING SYSTEMS

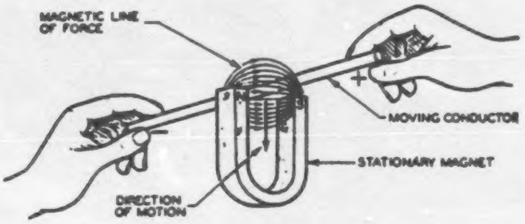
1. INTRODUCTION TO GENERATORS. Periodically, we are informed through the news media of areas in the country that are suffering from drought. Due to the lack of rain and snow the water supply has been reduced to a point where people no longer have the amount of water needed.

a. The electrical system of a wheeled vehicle can be compared to the situation above. The batteries are the heart of the electrical systems. A continuous drain on the batteries as a result of using lights, starter motor, horn, heater, etc, will soon cause them to reach a point of discharge where they can no longer furnish the amount of electrical power needed.

b. Wheeled vehicles contain a generating system that is designed to keep the batteries at the proper operating point and to assist the batteries in the job they have to do. The generating system, in conjunction with the batteries, produces the electrical current needed to operate all of the electrical components in the vehicle.

c. A generator is an electromagnetic device that changes mechanical energy (from the engine) into electrical energy. The automotive generator restores current to the battery that was used in cranking the engine (recharges the battery). It also supplies current to carry the electric load of lights, ignition, radio, etc. Most generators are mounted on the engine block in such a way that the engine fan belt drives the generator.

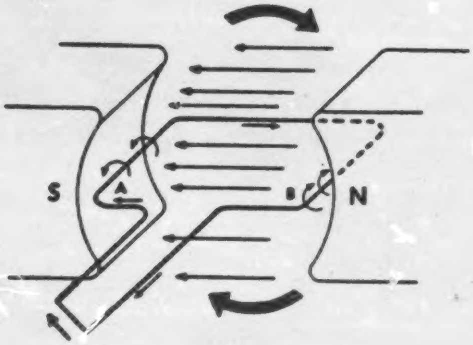
2. DIRECT CURRENT GENERATOR PRINCIPLES. We have seen, in a previous lesson on magnetism, that when a conductor (wire) is moved through a magnetic field, current will flow in the conductor if the two ends of the conductor are connected to complete the circuit. This current continues to flow in some direction as long as the conductor moves down. Current changes its direction of flow when the conductor is moved upward. This effect is sometimes called magnetic induction, because the electricity is induced by magnetism.



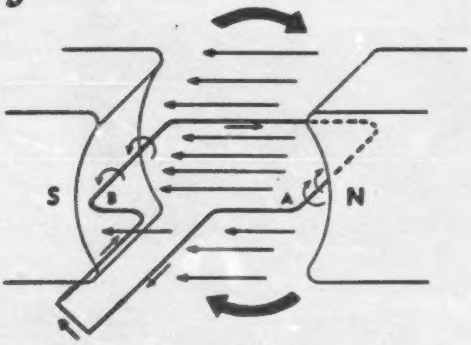
a. To get magnetic induction we must have three things; a magnetic field, conductor (complete circuit), and motion or movement between the magnetic field and the conductor.

b. If a single loop of wire is turned in the magnetic field between a north and south pole of a magnet, there will be an electrical pressure (voltage) induced or built up in the two sides of the loop. However, where the loop is turned, one side goes up and the other goes down. Because the two sides of the conductor in the magnetic field are moving in opposite directions, the induced current will flow in opposite directions. In the top ("A" section) of the figure the "B" side of the loop is moving down past the north pole of the magnet and the "A" side of the loop is moving up past the south pole. Current is leaving from the "B" side of the loop and is returning to the "A" side.

A



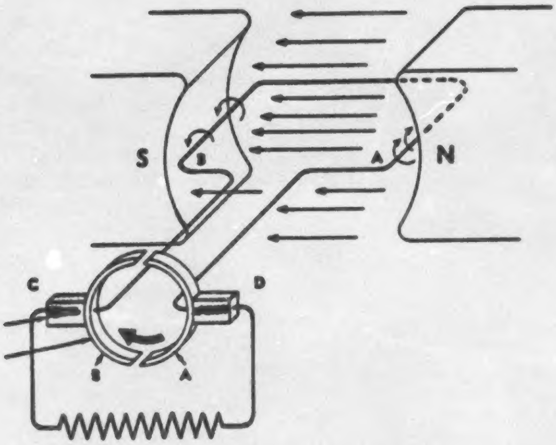
B



(1) In the "B" portion of the figure the loop has made a half turn. Now the "A" side of the loop is moving down past the north pole of the magnet and the "B" side is moving up past the south pole. The current is now leaving the "A" section of the loop and is returning to the "B" side of the loop. In other words, the current is alternating in the loop.

15b

(2) With the two ends connected as shown in the above example, current would only move or circulate within the loop of wire. If we want to take current out of the loop and pass it through an external circuit, we can do it by cutting into the loop and connecting part of a metal ring to each end of the loop. When the loop is rotated now, a potential will be placed on each part of the metal ring as shown by "A" and "B" in the figure. The parts of the ring we call segments. The two segments form a part that is called a commutator.

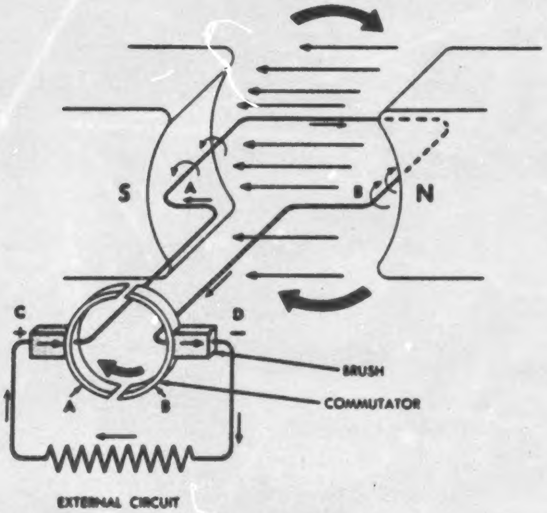


(3) Now lets add two brushes to pick up and return the current to the commutator. These are "C" and "D" in the figure and they are kept in contact with the commutator by springs.

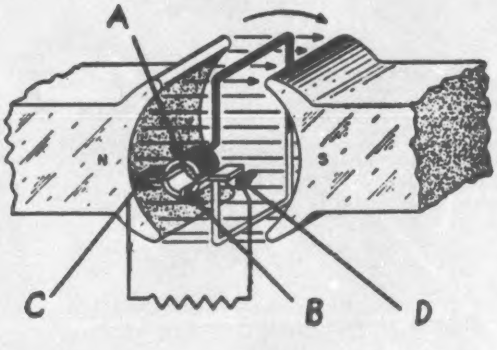
(4) The circuit can now be completed between the two brushes through an external circuit shown as a resistor for the load.

c. Now let's see what happens when we spin the loop in the magnetic field.

(1) In the figure, the "B" side of the loop is moving down past the north pole of the magnet while the "A" side is moving up past the south pole. At this time current will flow from the "B" section of the loop to segment "B" of the commutator. Here it will be picked up by brush "D" and sent out through the external circuit to brush "C." It will then go into segment "A" and from there back into the "A" side of the loop.

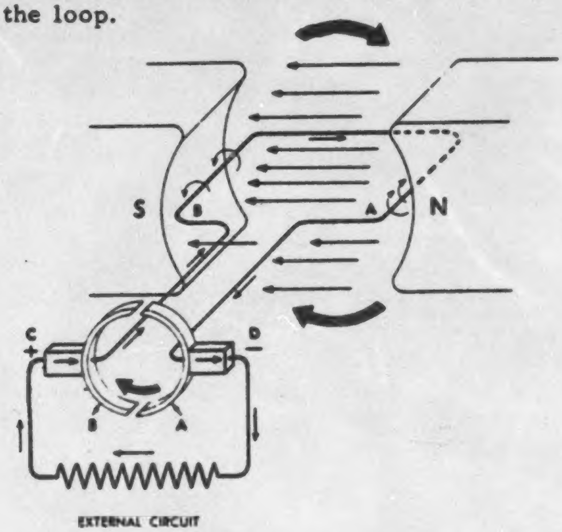


(2) Current will continue to flow until the loop is positioned straight up and down between the magnets. At this time the loop will be cutting through no lines of force so current flow stops.



(3) As the loop is turning, the segments are sliding under the brushes. By the time the loop reaches the up and down positions segment "B" will have moved enough so that it is ready to move from under brush "D" and move under brush "C." Segment "A" will be ready to move under brush "D."

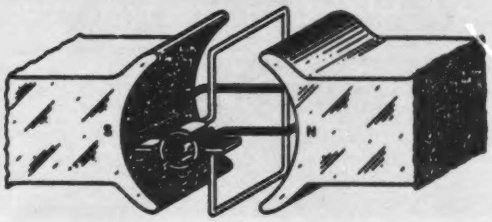
(4) As the loop continues to turn, the "A" side of the loop will start down past the north pole of the magnet. The "B" side of the loop will move up past the south pole. At this time current will be flowing out of the "A" side of the loop to the "A" segment. The "D" brush again picks up the current and sends it through the external circuit to the "C" brush and back to the "B" side of the loop.



(5) During one revolution of the loop there will be two pulses of current through the external circuit, both in the same direction. This is called direct current because it always flows in one direction through the load.

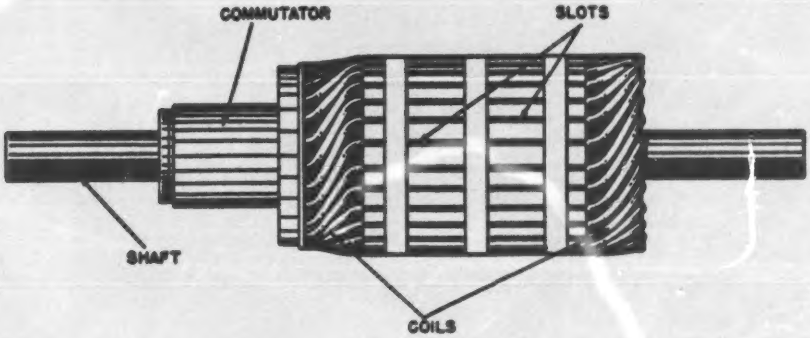
d. The current and voltage output of the generator, shown in the above figure, would be very low, because there are three things that determine a generator's output. They are the number of wires cutting the magnetic field, the speed with which they move through the magnetic field, and the strength of the magnetic field. An increase in any or all of these will result in an increase in generator output. Let's see what happens when we add another loop.

(1) This figure shows two loops of wire in the magnetic field. Also, two more segments have been added to the commutator. When these loops are turned we will get four pulsations of current instead of two.

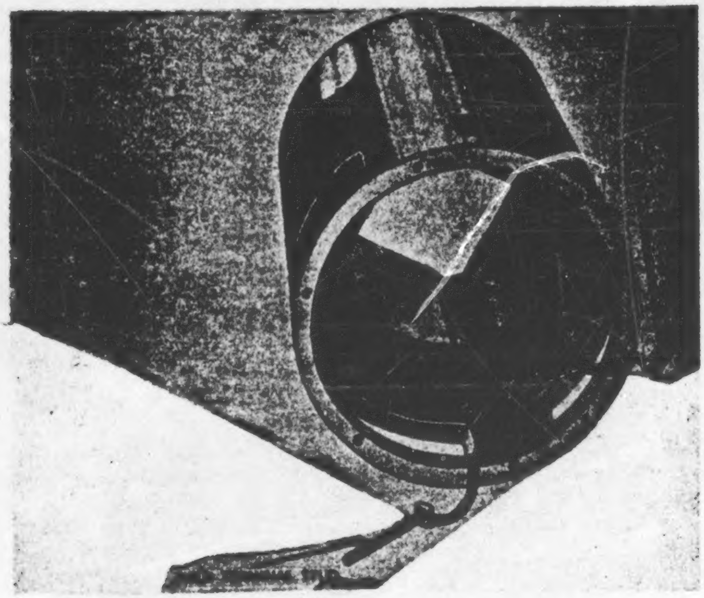


(2) In the generator with one loop, the generator output started with zero then built up to maximum and dropped back to zero for each half turn of the loop. When two loops are used at the time one loop is in the up and down position and producing no current, the other loop is producing maximum. So, in addition to getting four pulsations of current per revolution, the voltage does not drop to zero.

3. DC GENERATOR CONSTRUCTION. The actual generator you will be working with uses several loops instead of one. Also, each loop consists of several turns of wire. The loops are wound around an iron core and are attached to the segments that make up the commutator. The commutator, iron core, and windings are mounted on a shaft. The assembly is called an armature.



a. Instead of permanent magnets this generator has electromagnets. These are made up of a coil of wire, called a field coil, wrapped around an iron core or pole shoe. The pole shoes are secured to the inside of the generator housing or field frame by screws. One end of the field coils is grounded to the housing, the other comes out through the housing as the field terminal.



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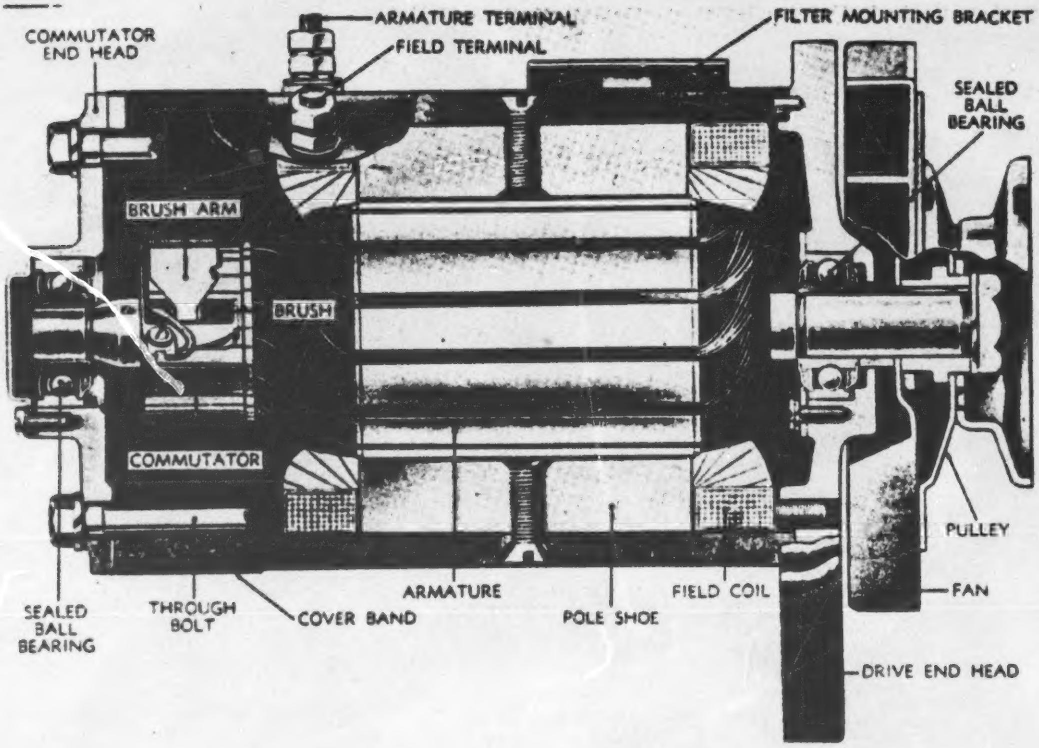
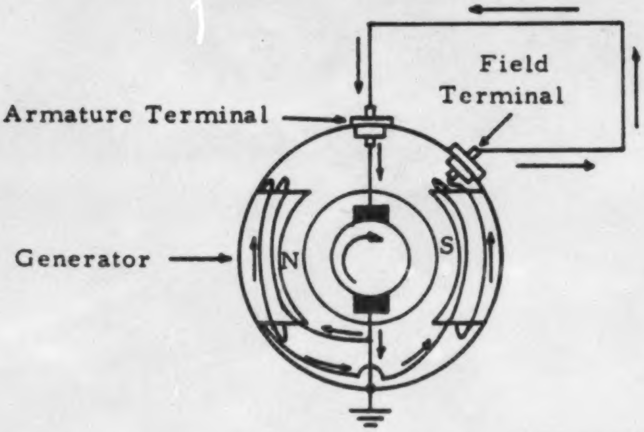
b. When the generator is assembled, the armature is placed inside the housing between the pole shoes. A cover called a drive-end head is mounted on one end of the housing. The drive-end head supports one end of the armature. Another cover, called a commutator-end head, goes on the other end of the housing and supports the other end of the armature. It also serves as a mount for the brushes. One brush is grounded to the commutator-end head. The other brush is connected by a wire to the armature terminal on the generator housing. On waterproof generators both of these terminals are enclosed in a waterproof outlet.


ARMATURE TERMINAL
FIELD TERMINAL
FILTER MOUNTING BRACKET
COMMUTATOR END HEAD
SEALED BALL BEARING
BRUSH ARM
BRUSH
COMMUTATOR
PULLEY
FAN
SEALED BALL BEARING
THROUGH BOLT
COVER BAND
ARMATURE
POLE SHOE
FIELD COIL
DRIVE END HEAD

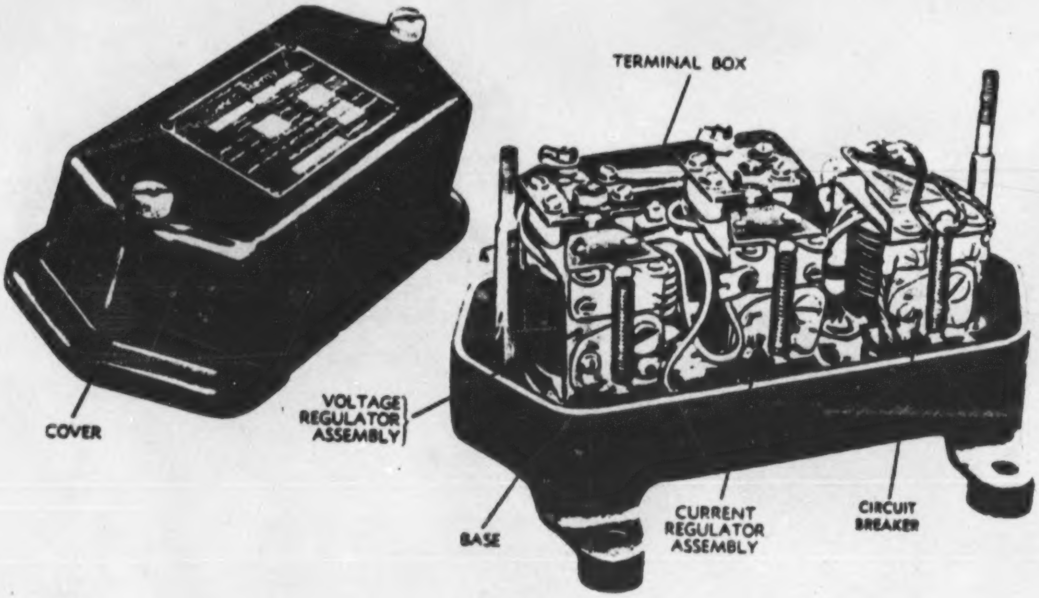
4. DC GENERATOR OPERATION. Several things are needed for this type generator to operate properly. One thing we must have is a magnetic field. You learned in a previous lesson that soft iron could be magnitized, but that when the magnetizing force is removed soft iron quickely loses most of its magnetism. Notice we said MOST. When the magnetizing force is removed, soft iron will retain a slight amount of magnetism. This is called residual magnetism. Let's just say for now that the pole shoes do contain residual magnetism.

a. Now let's see what takes place when this generator is put into operation. When the armature is turned, the armature coils will cut the weak magnetic field produced by the residual magnetism retained by the pole shoes. This sets up a small voltage (usually 1 to 1-1/2 volts) across the brushes which makes, in this particular case, the upper brush positive (+) and the lower brush negative (-). This voltage is enough to cause a small amount of current to flow from the negative brush through the field windings around the pole shoes. It then flows out the field terminal, through the external (outside) circuit, and back through the armature terminal and positive brush to the armature. When part of the current picked up by the brushes is sent through the field windings, the generator is said to be shunt (parallel) wound. All military wheeled vehicle DC generators are shunt wound.



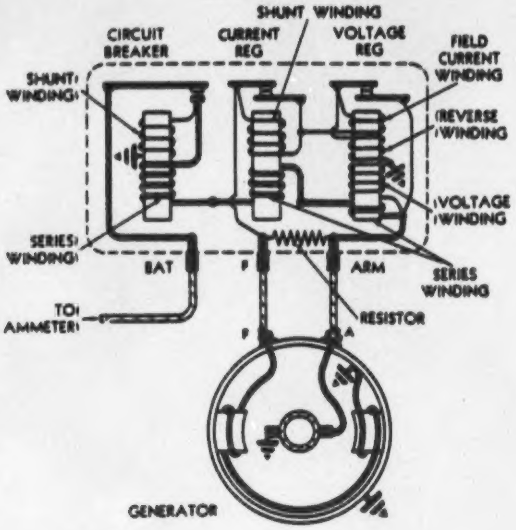
b. The small amount of current, produced by the residual magnetism, flowing through the field windings will increase the magnetic strength of the pole shoes. This, in turn, will increase the magnetic field through the armature. Since the armature coils now will be cutting more lines of force per turn, the voltage across the brushes will be increased. An increase in brush voltage increases the field strength which, in turn, increases the armature output. The armature voltage helps the field and the field helps the armature. This process, called "building up" the generator voltage, continues until the generator reaches its normal operating voltage.

5. **DC GENERATOR CONTROL.** Direct current generators need to be kept under control (regulated) to keep them from building up too much voltage and current. Without regulation, a generator will continue to increase its output as its speed increases. After a short time it will be producing so much current it will overheat and burn up. A generator which produces too much current and voltage will not only damage itself, but also the battery which it is charging and any other electrical equipment on the vehicle. There are several ways of regulating DC generator output, but the most common way on wheeled vehicles is by regulating the generator field current by the use of a generator regulator.



a. The complete generator regulator does three jobs. It disconnects the battery from the generator, when the generator is not charging, by the use of the circuit breaker. It prevents the generator from producing current above its rated output through the use of a current regulator. And it uses the voltage regulator to protect the battery and electrical components by keeping the voltage from going beyond a safe limit.

b. The generator regulator we are going to discuss contains three units one of which is a circuit breaker (also called cutout relay and reverse current relay). It acts as an automatic switch that completes the circuit from the generator to the battery when the generator is charging, and opens the circuit when it is not. This last action prevents the battery from discharging through the generator when the generator is not charging.



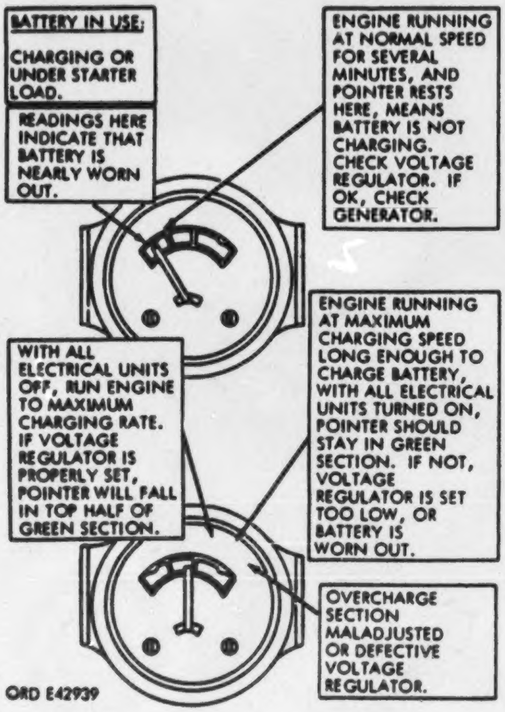
c. Another unit is the current regulator. Its purpose is to prevent the generator from destroying itself by delivering too much current. To control the current output of the generator, the current regulator controls the amount of current going through the fields by adding resistance to the field windings. When the current output of the generator starts to go too high, the current regulator puts resistance into the field circuit. This resistance may be put into and taken out of the generator field circuit as many as 200 times a second. The result is that the average of this resistance will limit the current to a safe value and keeps the generator from destroying itself.

d. The third unit is the voltage regulator. It operates much like the current regulator, except that it senses voltage instead of current and limits the generator's voltage to a safe value. This protects the battery and other electrical components from a voltage high enough to damage them.

6. DC CHARGING SYSTEM INSPECTION. An ammeter or battery indicator is connected between the generator regulator and the battery and is mounted on the instrument panel of a vehicle. This gives us a way of checking the action of the generator. Current flowing from the generator through the ammeter to the battery, when the engine is running, will cause the ammeter pointer to move in a positive or charge direction. If the engine is not running but the lights are on, the pointer will move in a negative or

discharge direction. Use of the ammeter to check the generating system can be of great help to both the operator and the repairman. Any indication of a constant high charge or discharge should be taken care of at once.

a. Most military vehicles use a battery indicator instead of an ammeter. The indicator is really a voltmeter that has a color coded scale instead of a numbered one. Notice in the figure how the different pointer portions can indicate the condition of the batteries and whether or not the generator has been doing its job.


BATTERY IN USE;
CHARGING OR UNDER STARTER LOAD.
READINGS HERE INDICATE THAT BATTERY IS NEARLY WORN OUT.
ENGINE RUNNING AT NORMAL SPEED FOR SEVERAL MINUTES, AND POINTER RESTS HERE, MEANS BATTERY IS NOT CHARGING. CHECK VOLTAGE REGULATOR. IF OK, CHECK GENERATOR.
WITH ALL ELECTRICAL UNITS OFF, RUN ENGINE TO MAXIMUM CHARGING RATE. IF VOLTAGE REGULATOR IS PROPERLY SET, POINTER WILL FALL IN TOP HALF OF GREEN SECTION.
ENGINE RUNNING AT MAXIMUM CHARGING SPEED LONG ENOUGH TO CHARGE BATTERY, WITH ALL ELECTRICAL UNITS TURNED ON, POINTER SHOULD STAY IN GREEN SECTION. IF NOT, VOLTAGE REGULATOR IS SET TOO LOW, OR BATTERY IS WORN OUT.
OVERCHARGE SECTION MALADJUSTED OR DEFECTIVE VOLTAGE REGULATOR.

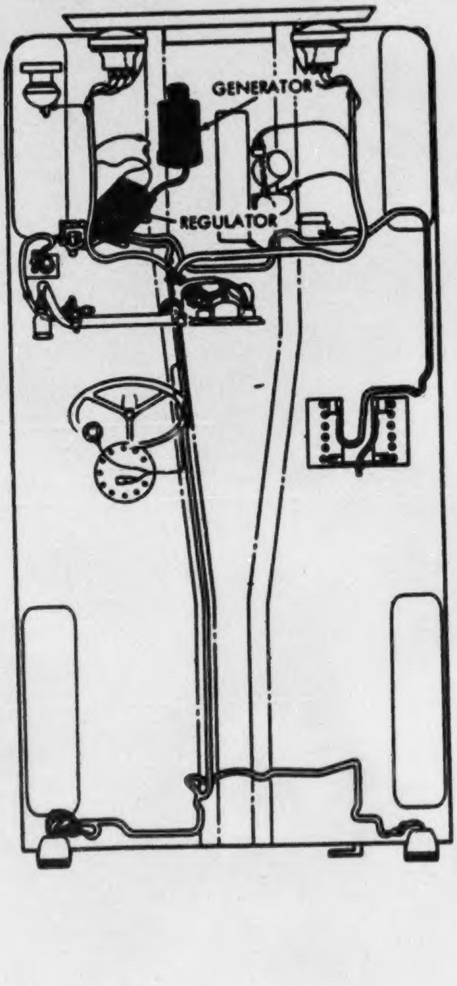
ORD E42939

b. The batteries themselves are also good indicators of what the charging system is doing. If the batteries must be charged very often by an outside source of current (a battery charger), the output of the vehicle generator is probably too low. On the other hand, if the water in the battery electrolyte is constantly boiling away, the generator voltage output is probably too high. When the generator output is too low, always check the drive (fan) belts. Slipping belts will cause a low output.

c. The drive belts are not the only things in the charging system you should inspect. Look for missing or loose generator mounting bolts and loose or damaged cables and connections. Correct any faults noted before testing the charging system.

7. DC CHARGING SYSTEM TESTING. To really pinpoint troubles in the DC charging system the low-voltage circuit tester (LVCT) and adapter kit are used. Before attempting to use the tester and adapter kit, review lesson 3 in this subcourse which described the tester, its meters, and controls. Don't forget to remove your watch and rings before working on any electrical circuits.

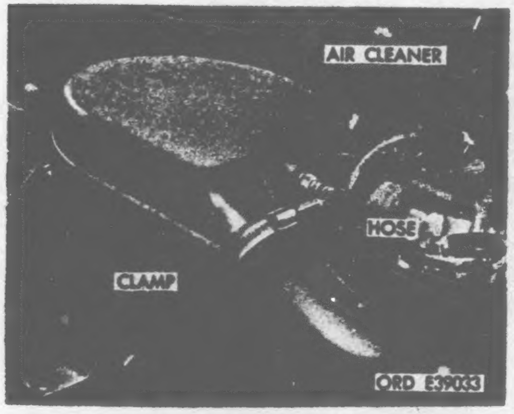
a. In this lesson we will use the M151, 1/4-ton truck with a 25-ampere charging system as an example, but the procedures for checking the DC charging systems of all Army wheeled vehicles are much the same. The location of the generator, regulator, and batteries used on the 1/4-ton truck are illustrated in the accompanying figure.

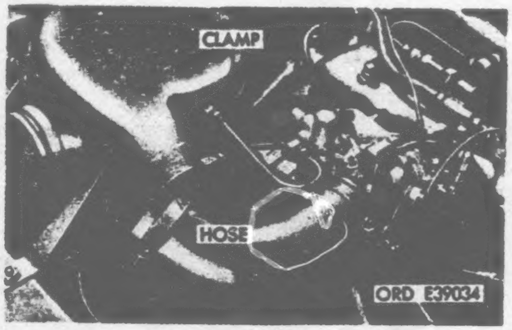


b. Connecting the LVCT into the generator circuit of an M151 is much easier if the carburetor air cleaner is removed, so let's see how this is done.

(1) First loosen the clamp screws and the clamps at the carburetor air intake hose. Now remove the hose from the air cleaner.

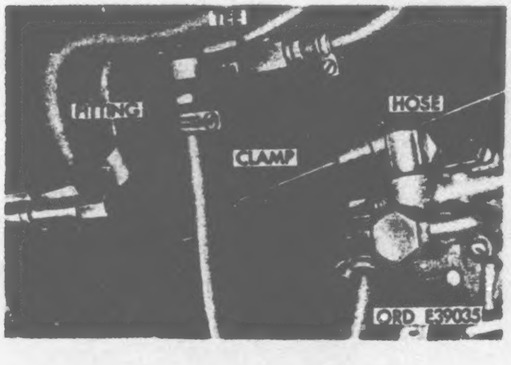
(2) Next loosen the clamp on the carburetor float chamber vent hose and pull the hose from the tube.

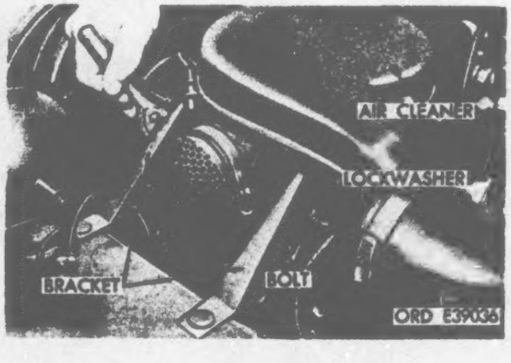

AIR CLEANER
HOSE
CLAMP
ORD E39033


CLAMP
HOSE
ORD E39034

(3) Unscrew the fuel tank vent hose fitting and then loosen the clamp on the fuel pump safety switch (oil pressure safety switch) vent hose. Then pull the hose off the tee.

(4) Next remove the four bolts and washers securing the air cleaner to the brackets, then remove the air cleaner.


TEE
FITTING
HOSE
CLAMP
ORD E39035

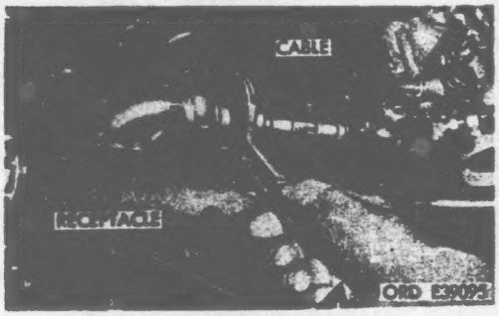

AIR CLEANER
LOCKWASHER
BRACKET
BOLT
ORD E39036

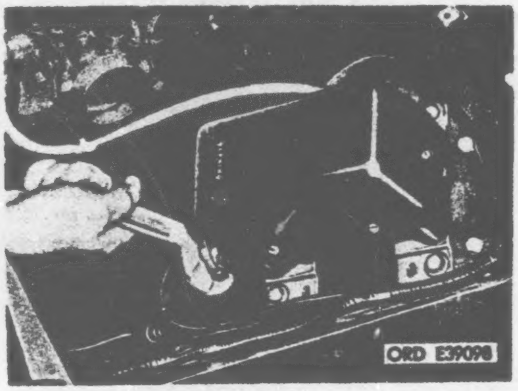
c. After the air cleaner is removed the adapters should be installed in the charging system. Here are the procedures for this.

(1) The battery ground cable of the vehicle should be disconnected before the adapters and test meters are connected into the charging circuit.

(2) Using a spanner wrench, disconnect and remove the generator to regulator wiring harness at the generator receptacle. Install the generator adapter in the receptacle and reconnect the harness to the adapter. Be sure both links of the adapter are open.

(3) Disconnect the main wiring harness connector at the regulator, install the adapter, and reconnect the harness.





GENERATOR
ADAPTER

REGULATOR
ADAPTER

d. The first test is the generator output test. We want to find out if the generator will produce the amount of current and voltage it is supposed to produce.

NOTE. - Refer to foldout illustration number 1 in the back of this pamphlet.

(1) In order to make this test, connect the meter leads as shown in the foldout. Notice the open links on the generator adapter and the closed link on the regulator adapter. Also notice the rheostats are turned all the way to the left (counterclockwise) and all of the switches on the LVCT are in the OFF position.

(2) Let's trace the charging circuit. The ammeter circuit negative lead is connected to the generator housing. From there it goes through the -50-ampere post to the ammeter in the LVCT. From the ammeter it goes through the load bank to the 24-volt post and then to the generator through the positive (red) ammeter lead. By having the load bank connected in series with the ammeter we can control the amount of current the generator is producing, at a given voltage, by moving the load bank control knob back and forth. This action raises or lowers the resistance in the armature or charging circuit of the generator. At this point you must reinstall the battery ground cable. Now to make the output test.

(3) Remember, earlier in the lesson we mentioned residual magnetism in the pole shoes. Well it is possible for this residual magnetism to be lost. If for some reason it is lost, it can be restored. To do this connect one end of a jumper wire to terminal 1 of the regulator adapter. Next, briefly touch the other end of the wire to field terminal F1 on the generator adapter. This sends current from the batteries through the field coils and causes them to magnitize the pole shoes. This is called polarizing the generator, or "flashing the fields."

(4) Start the engine and set the throttle so that the engine will run at about 1,500 RPM. Then turn the field rheostat clockwise until the voltmeter indicates 30 volts.

(5) Turn the load switch ON and turn the load bank control clockwise until the ammeter indicates 30 amperes. At the same time the field rheostat will have to be readjusted, for as the amperage increases the voltage will decrease. The generator should be able to produce 30 amperes and 30 volts. If the reading is less, and the drive belt is not slipping, the generator will have to be replaced. If the generator does produce and the test is being made because there is something wrong with the charging system, the problem will have to be in some other part of the system.

e. After checking the generator output the generator regulator can be tested. The first unit to be tested here is the reverse current relay (cutout relay). To do this, connect the meter leads as shown in foldout number 2.

(1) Notice the link on the regulator adapter is open. The ammeter leads are connected to the adapter as shown.

(2) On the generator adapter, the armature link is closed but the field link is open. The field rheostat and the voltmeter are connected as in the previous test.

(3) Place the voltmeter selector switch in the 50-volt position, crank the engine, and set the throttle so the engine runs at about 1,500 RPM.

(4) Slowly turn the field rheostat clockwise and watch both the voltmeter and the ammeter. The ammeter will read zero amperes until the reverse current relay points close. At the instant the ammeter needle moves, note the voltmeter. It should indicate slightly more than 25 volts but not over 26 volts. This is the closing voltage of the reverse current relay.

(5) Now slowly turn the field rheostat knob counterclockwise. Both the ammeter and voltmeter readings will drop. At the the instant the generator output voltage is equal to the battery voltage, the ammeter will read zero. Continue to turn the field rheostat knob counterclockwise. The ammeter will start to read on the discharge side of the meter. The batteries are now discharging through the generator, because the battery voltage is higher than the generator voltage. This discharge is called reverse current.

(6) Watch the ammeter closely and continue to turn the field rheostat counterclockwise. At between 1-1/2 and 7 amperes reverse current, the reverse current relay should open and the ammeter needle should return to zero on the scale.

(7) If the closing voltage and opening amperage is within these limits, the reverse current relay is OK. If not, replace the generator regulator.

f. The next unit to check is the voltage regulator. Before connecting the meter leads be sure both links on the armature adapter are closed and the link on the regulator adapter is open.

NOTE. - Refer to foldout illustration number 3.

(1) Connect the voltmeter leads as shown in foldout 3 and place the voltmeter selector switch in the 50-volt position.

(2) Crank the engine and set the throttle so the engine runs at about 1,500 RPM. If the voltage regulator is working correctly, the voltmeter reading should be not less than 27 volts nor more than 29 volts.

(3) If the voltmeter is not within these limits, replace the generator regulator.

g. The last unit to check is the current regulator. For this test, both generator adapter links should be closed and the regulator adapter link open.

NOTE. - Refer to foldout illustration number 4.

(1) Connect the ammeter leads as shown in foldout 4, turn the load bank control all the way counterclockwise, and turn the load bank switch OFF.

(2) Crank the engine and set the throttle so that the engine is running about 1,500 RPM.

(3) Turn the load bank switch on and rotate the load bank control clockwise until the ammeter shows a steady reading of 24 to 27 amperes. If the current is not in this range, the current regulator is at fault and generator regulator will have to be replaced.

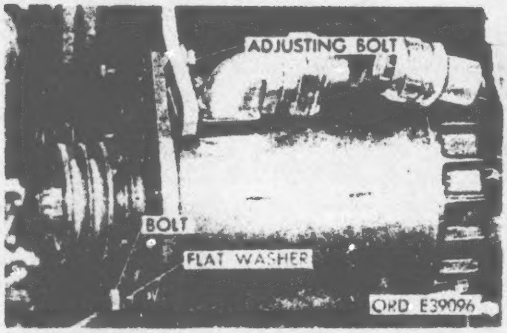
8. DC CHARGING SYSTEM COMPONENT REMOVAL AND REPLACEMENT. If the tests show that the generator or generator regulator are at fault they will have to be replaced. It will be your job to remove and replace these components.

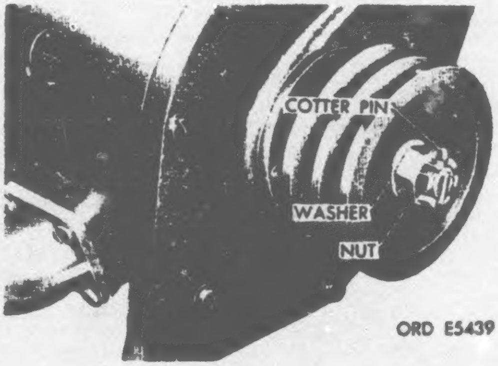
a. First, let's see just how you should go about removing and replacing the generator of an M151, 1/4-ton truck.

(1) If the air cleaner is still on the vehicle, it will have to be removed as previously described in this lesson. Also, the generator to wiring harness will have to be disconnected at the generator.

(2) Next, remove the generator adjusting arm bolt, lockwasher, and flatwasher from the adjusting arm and generator. Push the generator toward the engine and remove the drive belts.

(3) Now, remove the two nuts, lockwashers, and flatwashers from the generator mounting bracket. Remove the two mounting bolts from the generator and the mounting bracket and lift out the generator.

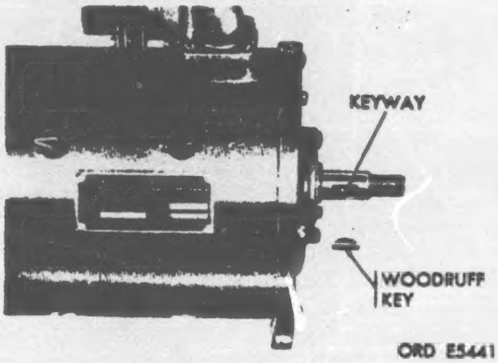




ORD E5439

(4) If the replacement generator does not come equipped with a drive pulley, the one from the old generator will have to be used. To do this, remove the cotter pin (if so equipped), washer, and nut that secures the pulley to the armature shaft. Throw the cotter pin away as a new one should be used.

(5) Remove the pulley from the generator armature shaft, using a suitable puller. Then remove the Woodruff key from the keyway in the armature shaft

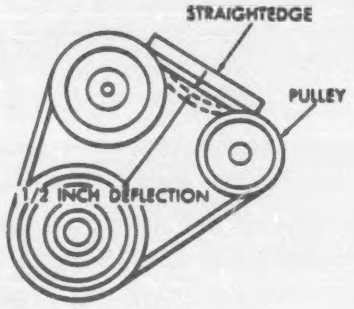


ORD E5441

(6) Install the pulley on the replacement generator. Be sure the spacer, Woodruff key, pulley, and washer are properly seated. The pulley nut, on generators using a cotter pin, should be torqued to 20 lb-ft, and on generators not using a cotter pin the torque should be 60 lb-ft.

(7) Install the replacement generator using the reverse of the removal procedures.

(8) To adjust the drive belt tension after the generator is installed, place a straightedge on the belt between the water pump and the generator pulley. Then move the generator away from the engine until the belt can be pushed down 1/2-inch, by pushing down firmly on the belt at a point halfway between the water pump and generator pulleys.



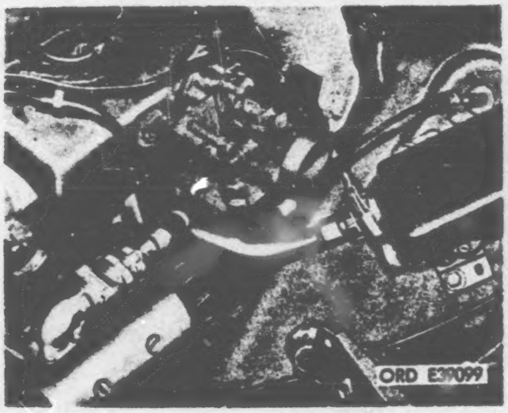
(9) With the proper belt tension, tighten the generator mounting bolts, generator adjusting bolt, and the adjusting arm to cylinder block bolt. The mounting bolts and/or nuts should be tightened to the following torque values: adjusting arm to cylinder block - 30-35 lb-ft, generator to mounting bracket nut - 60-70 lb-ft.

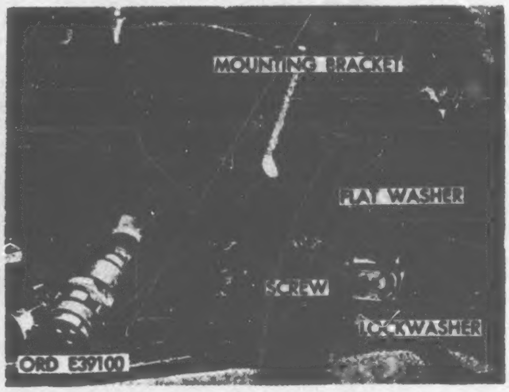
(10) Recheck the belt tension and replace the air cleaner using the reverse of the removal procedures.

b. The generator regulator is another component you will be required to remove. To do this, the battery cable will have to be disconnected, air cleaner hose removed, and the main wiring harness disconnected, using the same procedures used during the testing of the system.

(1) The spanner wrench is used to disconnect the generator to regulator cable connector at the regulator.

(2) Next, remove the four mounting screws, lockwashers, and flat washers. Then lift out the generator regulator with the mounting bracket attached.





(3) To install the replacement regulator follow the reverse of the removal steps. Torque the mounting screws to 9-12 lb-ft.

Note. - Complete exercises number 61 through 71 before continuing to section II.

61. Most generators used on wheeled vehicles are driven by

    a. gears.
    b. chains.
    c. belts.

62. The DC generator used on tactical wheeled vehicles is known as a

    a. shunt-wound generator.
    b. series-wound generator.
    c. compound-wound generator.

63. The drive pulley on the 25-ampere generator is mounted on the

    a. armature shaft.
    b. rotor shaft.
    c. stator shaft.

64. The field windings in a DC generator are wound around the

    a. armature.
    b. pole shoes.
    c. frame.

65. The output of DC generators used on wheeled vehicles is controlled by the

    a. size of the conductors.
    b. generator field strength.
    c. speed of the engine.

66. What protects the DC generator used on wheeled vehicles from being overloaded?

    a. Circuit breaker
    b. Voltage regulator
    c. Current regulator

67. In the DC charging system what prevents the batteries from being overcharged?

    a. Circuit breaker
    b. Voltage regulator
    c. Current regulator

68. What is used to polarize the generator?

    a. A battery
    b. The field windings
    c. A rectifier

69. The battery indicator used on most military vehicles is really

    a. a voltmeter.
    b. an ammeter.
    c. a flowmeter.

70. What unit is connected in series with the ammeter on the LVCT when testing the DC generator output?

    a. Load bank
    b. Voltmeter
    c. Field rheostat

71. What tool is used to remove the generator wiring harness from the 25-ampere generator used on military vehicles?

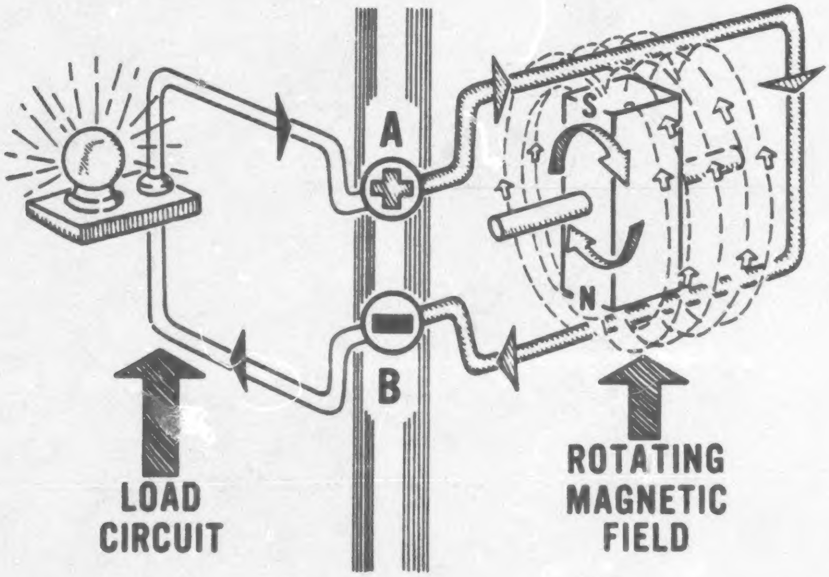
    a. Screwdriver
    b. Open end wrench
    c. Spanner wrench

## SECTION II. AC GENERATING SYSTEMS

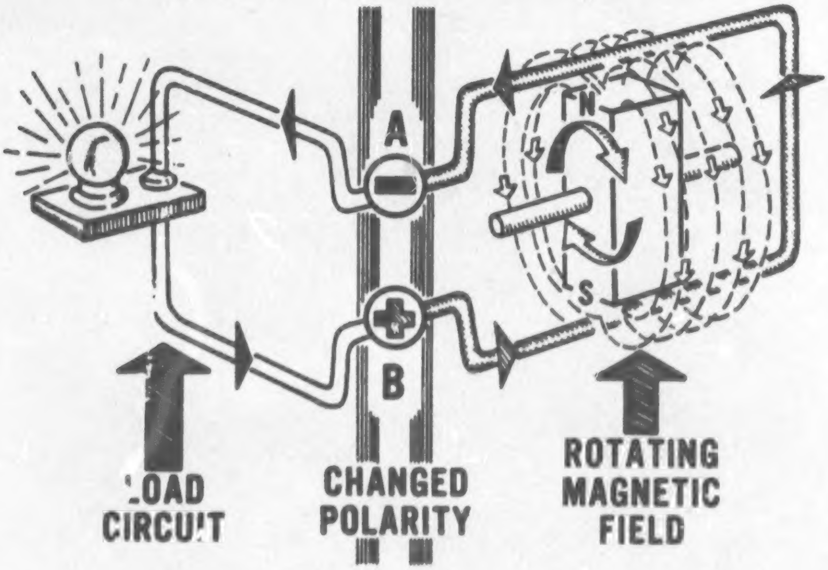
9. AC GENERATOR CONSTRUCTION AND OPERATION. The DC charging system we have discussed has a 25-ampere generator. For a normal military vehicle, 25 amperes is enough current to operate all the electrical equipment and to keep the batteries charged. But for tactical needs in combat, large radios and transmitters are often mounted in vehicles. These need much more current than the 25-ampere generator can supply. We could use a larger DC generator, but to operate the radio we would have to operate the vehicle engine at a high speed. This would cause unnecessary engine wear and fuel waste. The noise of the engine would also alert the enemy that you were in the area. To solve this problem several alternating current generating systems were developed that will produce a lot of current even at a low engine speed. The AC (alternating current) generators are more commonly called alternators.

a. We learned that in a direct current generator the conductors turned in a stationary magnetic field. This action caused the loops of wire to cut the magnetic field and produce current flow. In the AC generator we are going to discuss, the magnetic field is turned and the stationary conductors are cut by the moving magnetic lines of force. In a simple AC generator having one loop, the turning bar magnet furnishes the moving field.

(1) In the figure, the north pole of the magnet passes the lower leg of the loop. As a result, current is induced in the loop in the direction shown by the arrows.



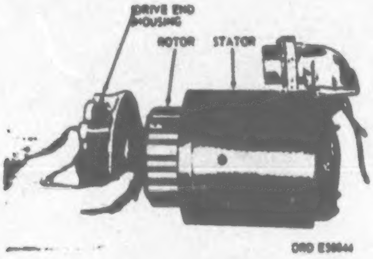
(2) In this figure, the magnet has turned half a turn and its south pole is passing the lower leg of the loop and the north pole is passing the upper leg. The magnetic field is now reversed and current flow in the loop will be in the direction indicated by the arrows.



(3) As the magnet spins and the two poles pass the two legs of the loop, electrons are pushed first in one direction and then in the other. This causes alternating current to flow in the external circuit.

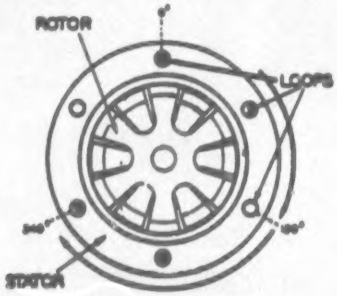
(4) The amount of voltage and current produced by the generator is determined by the strength of the magnetic field, the number of conductors, and the speed of the spinning magnet. The alternator you will be working with has a strong magnetic field and a large number of loops.

b. Instead of a simple bar magnet, the turning part (or rotor) of an alternator is made up of an iron core fastened to a shaft, with windings wound into machined slots in the core. The ends of the windings are connected to sliprings or contact rings. In the 100-ampere alternator used on some military vehicles there are 12 windings, each one having several turns of wire.

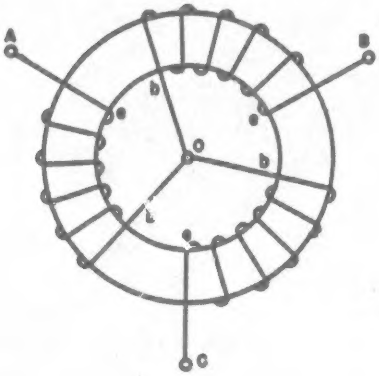


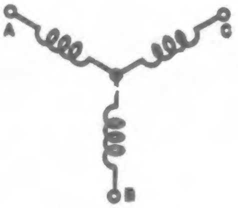
c. In a rotor made like this, if a battery is connected to the slip-rings by means of brushes current will flow through all the windings. This will make the iron core a very strong electromagnet. The core has 12 poles (six north and six south). Now, instead of having one bar magnet we will have six very strong electromagnets. We can control the strength of these magnets, as we did in the DC generator, by controlling the amount of current sent to the electromagnetic rotor. When we turn this rotor we will have a strong magnetic field which will be moving.

d. Now we need conductors which are not moving in this magnetic field. The conductors are assembled on a housing which is called a stator. The stator is made by winding three loops of wire on a housing or frame of soft iron. Each loop is made up of many turns of wire. When the alternator is assembled the rotor will go inside the stator.



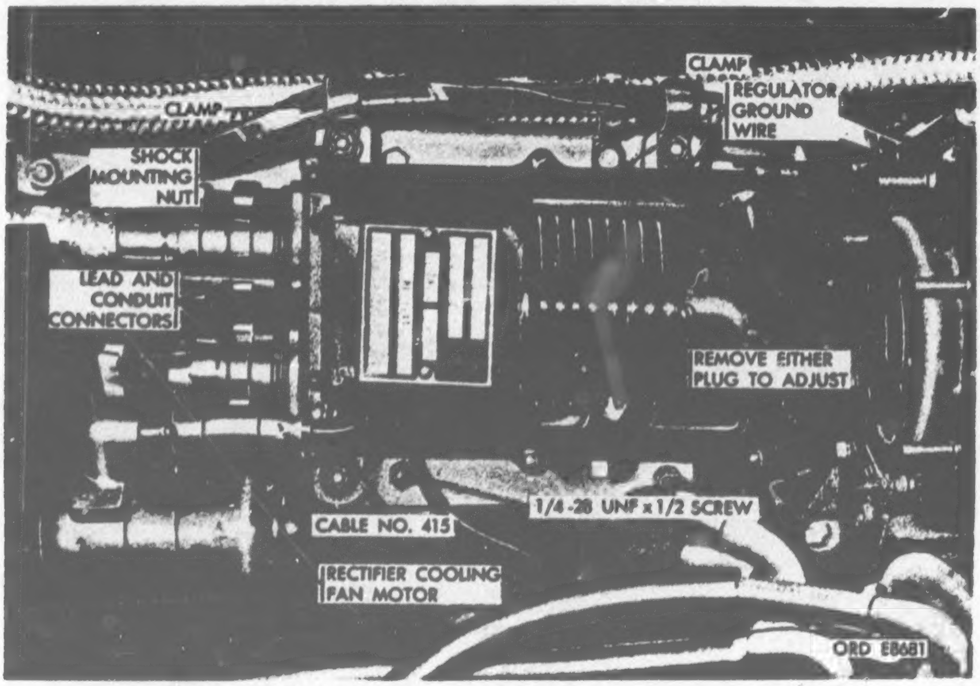
e. The stator windings are connected as shown in the figure. One end of each of the loops are brought together and fastened. The three ends that are left are the three terminals from which current is taken or returned to the alternator. This type alternator is called a three-phase alternator. When it is operating it will give a steady supply of alternating current.





SCHEMATIC

10. ALTERNATOR CONTROL. All vehicle charging systems need a voltage regulator to keep the generator voltage from going high enough to damage the battery or other parts of the system. The 100-ampere alternator regulator used on the M151, 1/4-ton truck is a carbon pile voltage regulator. It consists of a stack of thin carbon disks, held together by the pressure of a spring, and an electromagnet which is used to control the spring pressure. This, in turn, will control the amount of current being sent through the alternator's rotor windings. The resistance of the carbon disks depends on how tightly they are compressed or pressed together.


CLAMP
REGULATOR GROUND WIRE
CLAMP
SHOCK MOUNTING NUT
LEAD AND CONDUIT CONNECTORS
REMOVE EITHER PLUG TO ADJUST
1/4-28 UNF x 1/2 SCREW
CABLE NO. 415
RECTIFIER COOLING FAN MOTOR
ORD E8681

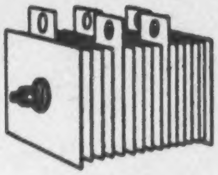
a. An adjusting rheostat (resistor) is used to allow the organizational repairman to adjust the voltage.

b. A load relay is used to feed battery current through the rotor to start the alternator charging. The alternator does not have a residual magnetism to start charging by itself like a DC generator.

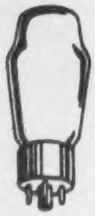
c. A rectifier (which we will discuss later) is used in this system. It will allow current to flow in one direction only, in this case from the alternator to the battery. This being true, the battery can not discharge through the alternator so we do not need a cutout relay (circuit breaker). Also, the alternator is made to produce not more than 100 amperes so a current regulator is not needed.

d. You already know that direct current (DC) is used in the vehicle's electrical system and to charge the battery. The alternator produces alternating current (AC). This means we must have some way to change AC to DC. This is done by means of a unit called a rectifier.

METALLIC RECTIFIER



VACUUM TUBE RECTIFIER



(1) A rectifier acts a little like a one-way valve in a waterline, it lets current flow in one direction but not the other. The unit used with the 100-ampere alternator is actually six rectifiers. They are connected in the circuit in such a way that all the current output of the alternator is changed to DC and fed to the vehicle's batteries and electrical circuits.

(2) Heavy current flowing through the rectifier causes heat. On some vehicles, a cooling fan is used to help cool the rectifier. On others, the engine's cooling fan is used to cool the rectifier.

(3) Care should be taken to prevent the batteries from being put in the vehicle backward (with reverse polarity). If this should happen, the alternator could not send current through the battery. However, the battery could discharge through the alternator. This would burn up the rectifier and regulator.

11. INSPECTION AND TESTING AC SYSTEMS. Inspection includes checking the fan and generator belt tension. All belts should have about 1/2 inch free play. Next check the generator, regulator, and rectifier mounting screws, bolts, and nuts for tightness. Then check all cable connectors for tightness and inspect all wiring harnesses and conduits. Check the battery cables for tightness and condition. Tighten, clean, or replace cables are required. Turn the ignition switch on to see if the rectifier cooling fan is operating. Check to see if the fan is unusually noisy and if it is producing a strong breeze. Now start the engine. The battery-generator indicator pointer on the instrument panel should move to the upper portion of the orange band or lower portion of the green band. Allow the engine to reach operating temperature and observe the battery-generator indicator. With the engine operating at 1,500 RPM, the

indicator pointer should read in the green band. Turn the ignition switch off. If the pointer did not move to the proper scale, the voltage regulator may be out of adjustment.

a. To perform a voltage output test, connect a DC voltmeter having a 50-volt range to the positive terminal of the ungrounded battery and the negative terminal of the other battery. Turn the ignition switch on. The battery-generator indicator pointer should be in the orange block and the voltmeter should read between 23 and 25 volts. Depress the starter switch with the ignition switch off. Observe the voltmeter. If the voltmeter reads less than 18 volts while cranking the engine, charge or replace the batteries.

b. Start the engine and allow it to reach operating temperature. With the voltmeter connected across the batteries and the engine at high idle (1,500 RPM), the voltmeter should read 28 volts ± 1 volt. At this time the battery-generator indicator pointer should read in the green block. Turn on the lights or any load not over 100 amperes. The voltage reading should remain constant at between 27 and 29 volts. If the voltage drops below 27 or goes over 29 volts during the test, adjust the regulator voltage.

c. Remove the access plug from the top or side of the regulator. Using a common screwdriver turn the voltage adjusting rheostat (resistor) in a clockwise direction to increase voltage or in a counterclockwise direction to decrease voltage. The rheostat should not allow more than a 5-volt range in its adjustment and the voltmeter reading should remain stable.

12. MAINTENANCE OF THE 60 AMPERE, SELF-CONTAINED ALTERNATOR. An alternator of a new design is also being used on the 1/4-ton truck and larger vehicle. It is a self-contained, 60-ampere, 3-phase alternator. By self-contained we mean that the rectifiers (also called diodes) and the current and voltage regulators are built into the generator (alternator).

a. The rectifiers are the solid state type and are mounted on a cooling fin assembly for heat dissipation.

b. Organizational maintenance personnel are not authorized to adjust the regulators. They may, however, be adjusted by support maintenance personnel.

c. The procedures for adjusting the drive belts and for removing and replacing the alternator assembly are similar to those described for the 25-ampere DC generator.

13. 60-AMPERE, 3-PHASE, ALTERNATOR VOLTAGE TEST.

a. Purpose. To check the voltage output of the alternator.

b. Hookup procedure.

**Note.** - Remove alternator terminal cover and operate engine at ____ RPM as per technical manual for 15 minutes prior to testing.

(1) Stop engine and connect the voltmeter leads to the positive and negative binding posts of the voltmeter on the LVCT.

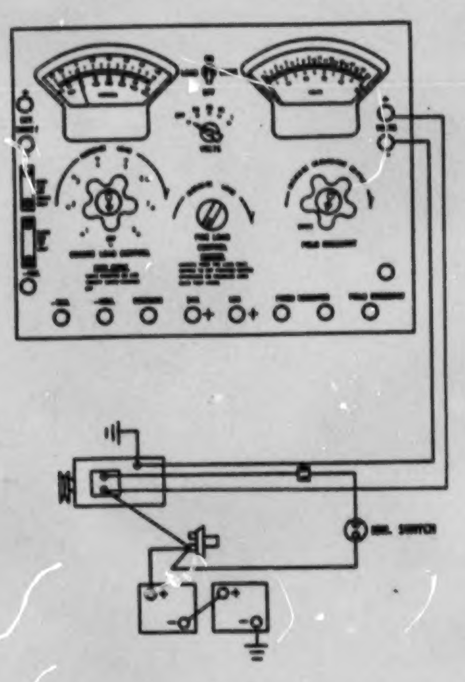
(2) Connect the positive lead to the alternator output terminal and the negative lead to the alternator ground terminal.

(3) Start and operate engine at ____ RPM as per technical manual.

(4) Turn the voltmeter selector switch to the 50-volt position; the voltmeter should read 28 ±1 volt. If the voltage is less than 27 volts, stop the engine and note the voltage indicated. If the voltage reading remains the same as when the engine was running, proceed to Test No 2 (Ignition Sensing Lead Continuity Test). If the voltmeter indicates that the alternator is charging but the charging rate is higher than 28. 5 or lower than 27. 5, remove the plug from the front flange of the alternator. Use a small screwdriver and turn the voltage adjusting screw until the voltmeter reads exactly 28 volts.

**Note.** - Use extreme caution to avoid contact with the engine fan when performing this test.

(5) If the voltage cannot be adjusted to the correct specification, a faulty alternator is indicated.



## 14. IGNITION SENSING LEAD CONTINUITY TEST.

a. Purpose. To determine whether or not battery voltage and current are reaching the alternator field circuit through the ignition sensing lead.

b. Hookup procedure.

Note. - Unplug the ignition sensing lead (wire No 468) from the alternator.

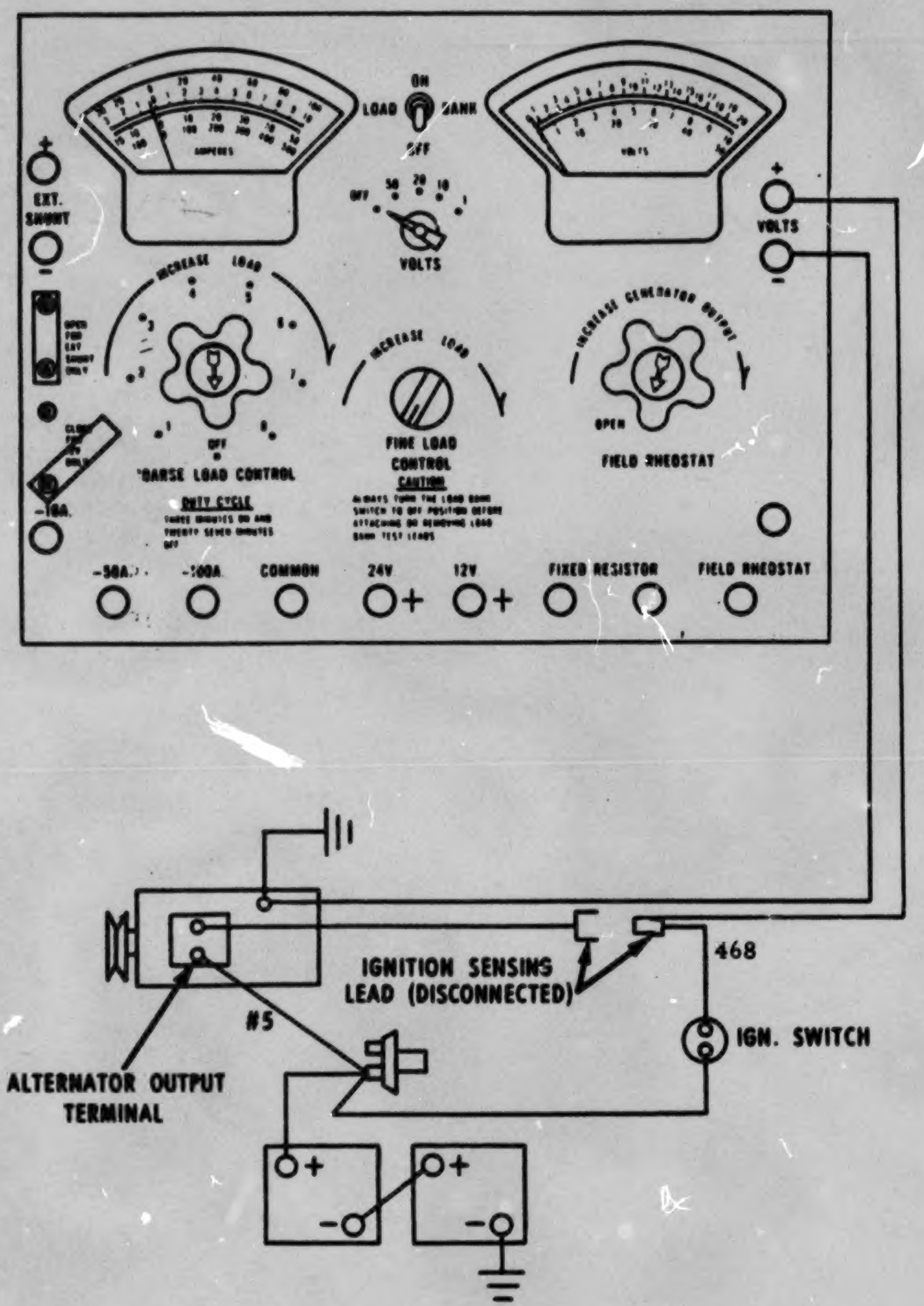
(1) Connect the positive and negative voltmeter leads to the corresponding binding posts of the voltmeter on the LVCT.

(2) Connect the positive lead to the ignition sensing lead (wire No 468) and the negative lead to the alternator ground terminal.

(3) With the ignition switch turned on, the voltmeter should indicate battery voltage (24 ±1 volt). If no or low voltage is obtained, repair or replace wire No 468.

(4) Once the wire is repaired and tested, repeat the Alternator Output Test (Test No 1). If the alternator still has no output, replace it. If the output voltage is greater than 28.5 volts or less than 27.5 volts, remove the plug from the front flange of the alternator and, using a small ignition screwdriver, adjust the output voltage to exactly 28 volts.

Note. - Use caution when performing this adjustment since your hands will be near the turning fan blades. If the output voltage cannot be adjusted to 28 volts, a faulty alternator is indicated.


AMPERES
LOAD
ON
BANK
OFF
VOLTS
OFF
50
20
10
VOLTS
+
EXT. SHUNT
−
OPEN FOR EXT SHUNT ONLY
CLOSE FOR EXT ONLY
−10A.
INCREASE LOAD
OFF
COARSE LOAD CONTROL
DUTY CYCLE
THREE MINUTES ON AND TWENTY SEVEN MINUTES OFF
INCREASE LOAD
FINE LOAD CONTROL
CAUTION
ALWAYS TURN THE LOAD BANK SWITCH TO OFF POSITION BEFORE ATTACHING OR REMOVING LOAD BANK TEST LEADS
INCREASE GENERATOR OUTPUT
OPEN
FIELD RHEOSTAT
+
VOLTS
−
−50A.
−100A.
COMMON
24V
+
12V
+
FIXED RESISTOR
FIELD RHEOSTAT
IGNITION SENSING LEAD (DISCONNECTED)
468
IGN. SWITCH
#5
ALTERNATOR OUTPUT TERMINAL
+
−
+
−

185

## 15. ALTERNATOR LOAD TEST.

a. Purpose. To determine whether or not the alternator is capable of producing its rated voltage and amperage.

b. Hookup procedure.

(1) Connect the positive and negative voltmeter leads to the corresponding binding posts of the voltmeter on the LVCT.

(2) Connect the positive voltmeter lead to the positive terminal of the ungrounded battery and connect the negative lead to the negative terminal of the grounded battery.

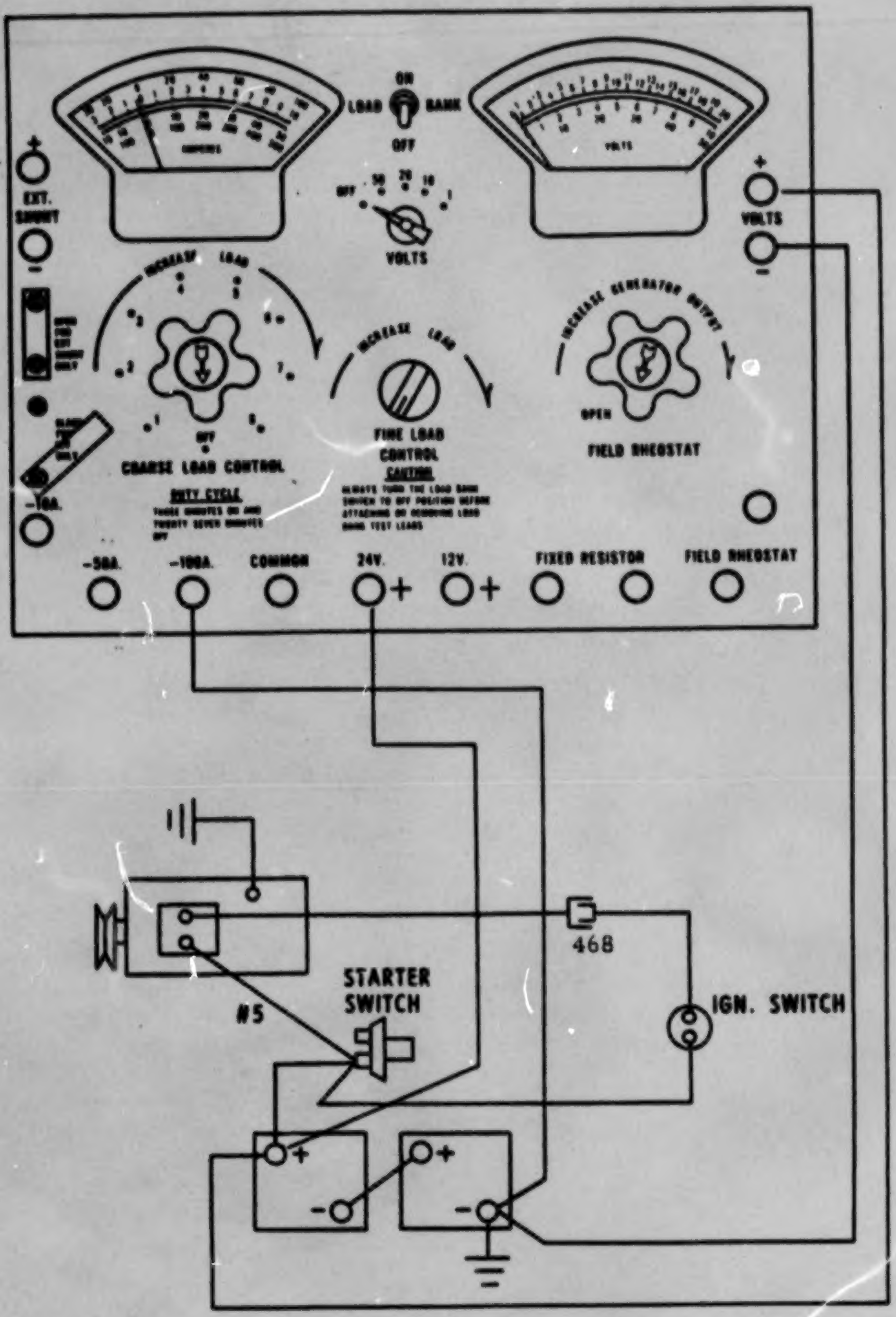
(3) Connect one end of the negative ammeter lead to the -100-amp binding post of the LVCT and the other end to the negative terminal of the grounded battery.

(4) Connect one end of the positive ammeter lead to the +24-volt binding post of the LVCT and the other end to the positive terminal of the ungrounded battery.

Note. - Make sure load bank control knob and switch are in the off position prior to starting the engine, and open the load bank link.

(5) Operate the engine at ____ RPM as per technical manual for 15 minutes prior to test.

(6) With the engine running at ____ RPM as per technical manual, the voltmeter range selector on the 50-volt range, and the load bank switch turned on, gradually turn the load bank control knob clockwise until the ammeter indicates 40 amperes. At this time, note the voltmeter reading; it should indicate between 27.5 to 28.5 volts. If the voltage is not within these specifications, remove the plug from the front flange of the alternator and adjust the voltage output to 28 volts. If this adjustment cannot be obtained, perform the Alternator-to-Battery-Cable and Ground Cable Resistance Tests (Tests No 4 and 5).


LOAD
ON
BANK
OFF
AMPERES
VOLTS
OFF
50
20
10
1
VOLTS
+
EXT.
SHUNT
−
INCREASE LOAD
OFF
COARSE LOAD CONTROL
DUTY CYCLE
THREE MINUTES ON AND TWENTY SEVEN MINUTES OFF
INCREASE LOAD
FINE LOAD CONTROL
CAUTION
ALWAYS TURN THE LOAD BANK SWITCH TO OFF POSITION BEFORE ATTACHING OR REMOVING LOAD BANK TEST LEADS
INCREASE GENERATOR OUTPUT
OPEN
FIELD RHEOSTAT
+
VOLTS
−
−10A.
−50A.
−100A.
COMMON
24V.
12V.
FIXED RESISTOR
FIELD RHEOSTAT
+
+
468
STARTER
SWITCH
#5
IGN. SWITCH
+
+
−
−

187

## 16. ALTERNATOR-TO-BATTERY-CABLE TEST.

a. Purpose. To check for high resistance due to faulty cables or poor connections between the alternator and batteries.

b. Hookup procedure.

(1) Connect one end of the negative ammeter lead to the -100 ampere binding post of the LVCT and the clip end to the negative post of the grounded battery.

(2) Connect the positive ammeter lead to the +24-volt binding post of the LVCT and the clip end to the positive post of the ungrounded battery.

(3) Connect the positive and negative voltmeter leads to the corresponding binding posts on the LVCT.

(4) Connect the clip end of the positive voltmeter lead to the alternator output terminal and the clip end of the negative voltmeter lead directly to the positive post of the ungrounded battery.

Note. - Make sure that the load bank control knob and switch are in the off position and that the load bank link is open before starting the engine.

(5) Start and operate the engine at ____ RPM as per technical manual for 15 minutes prior to making test, then proceed as follows: Turn load bank switch on and, with the engine still operating at ____ RPM, slowly turn the load bank knob clockwise until the ammeter reads 40 amperes. Turn the voltmeter switch to the 50-volt position then progressively downward until a reading is obtained or the 1-volt position is reached.

(6) The voltmeter should not exceed 0. 5 volts. A reading of more than 0. 5 volts indicates faulty alternator to battery cables or connections.

(7) To pinpoint a faulty cable or connection, leave the positive voltmeter lead connected to the alternator terminal and connect the negative voltmeter lead to the battery side of the starter switch. If the voltmeter reads more than 0. 3 volts, excessive resistance exists between the alternator and starter switch. If the reading is 0. 3 volts or less and the overall reading in the previous test was more than 0. 5 volts, high resistance exists between the battery and starter switch.

(8) Eliminate excessive resistance by cleaning and tightening connections or by replacing cables as required.

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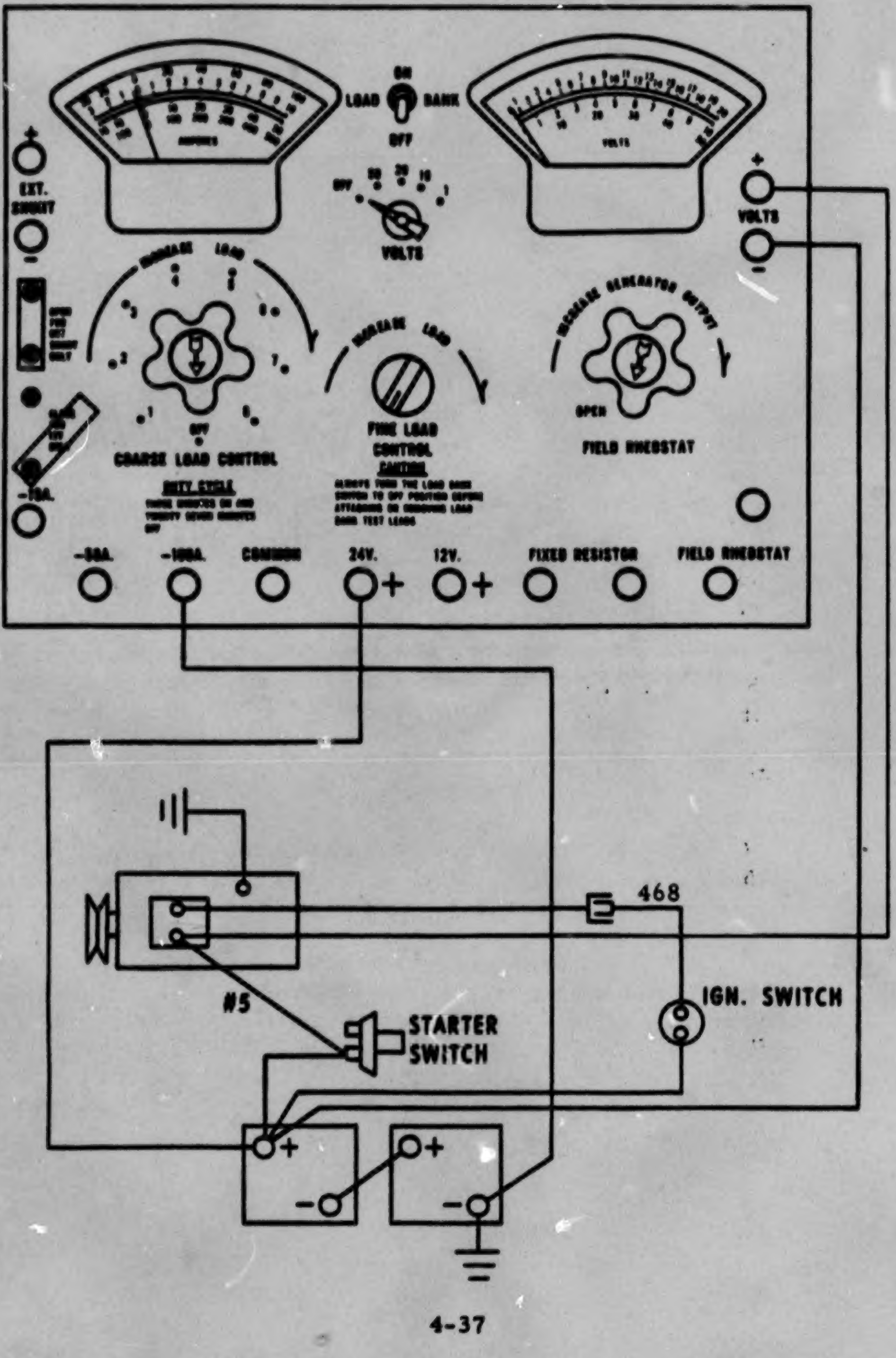
+
EXT.
SHUNT
−
ON
LOAD
BANK
OFF
VOLTS
VOLTS
+
−
INCREASE LOAD
COARSE LOAD CONTROL
DUTY CYCLE
THREE MINUTES ON AND
TWENTY SEVEN MINUTES
OFF
INCREASE LOAD
FINE LOAD
CONTROL
CAUTION
ALWAYS TURN THE LOAD BANK
SWITCH TO OFF POSITION BEFORE
ATTACHING OR REMOVING LOAD
BANK TEST LEADS
INCREASE GENERATOR OUTPUT
OPEN
FIELD RHEOSTAT
−10A.
−50A.
−100A.
COMMON
24V. +
12V. +
FIXED RESISTOR
FIELD RHEOSTAT
468
IGN. SWITCH
#5
STARTER
SWITCH
+
+
−
−

## 17. ALTERNATOR GROUND CIRCUIT RESISTANCE TEST.

a. Purpose. To check battery and alternator ground cables and connections for excessive resistance.

b. Hookup procedure.

(1) Turn load bank switch to off position, turn load bank control knobs to fully off position, and open the load bank link.

(2) Connect the positive ammeter lead to the +24-volt binding post of the LVCT and the clip end of the positive ammeter lead to the positive post of the ungrounded battery.

(3) Connect the negative ammeter lead to the -100-ampere binding post of the LVCT and the clip end of the negative ammeter lead to the negative post of the grounded battery.

(4) Connect the positive and negative voltmeter leads to the corresponding binding posts on the LVCT. Connect the clip end of the positive voltmeter lead directly to the negative post of the grounded battery and the clip end of the negative lead to the alternator ground cable.

(5) Start and operate the engine at ____ RPM as per technical manual for 15 minutes. Close the load bank switch and slowly turn the load bank control knobs until the ammeter reads exactly 40 amperes. Turn the voltmeter selector switch to the 50-volt position then progressively downward to the 1-volt position or until a reading is obtained.

(6) The voltmeter should not read more than 0.2 volt. An excessive voltage reading indicates high resistance in the ground cables or connections. High resistance can be eliminated by cleaning and tightening the battery and alternator ground connections or by replacing the ground cables as necessary.

(7) After the alternator to battery cables and the ground circuit cables have been tested and resistance eliminated, repeat the alternator output test. If the alternator cannot be adjusted to produce 40 amperes and 28 volts, a faulty alternator is indicated.

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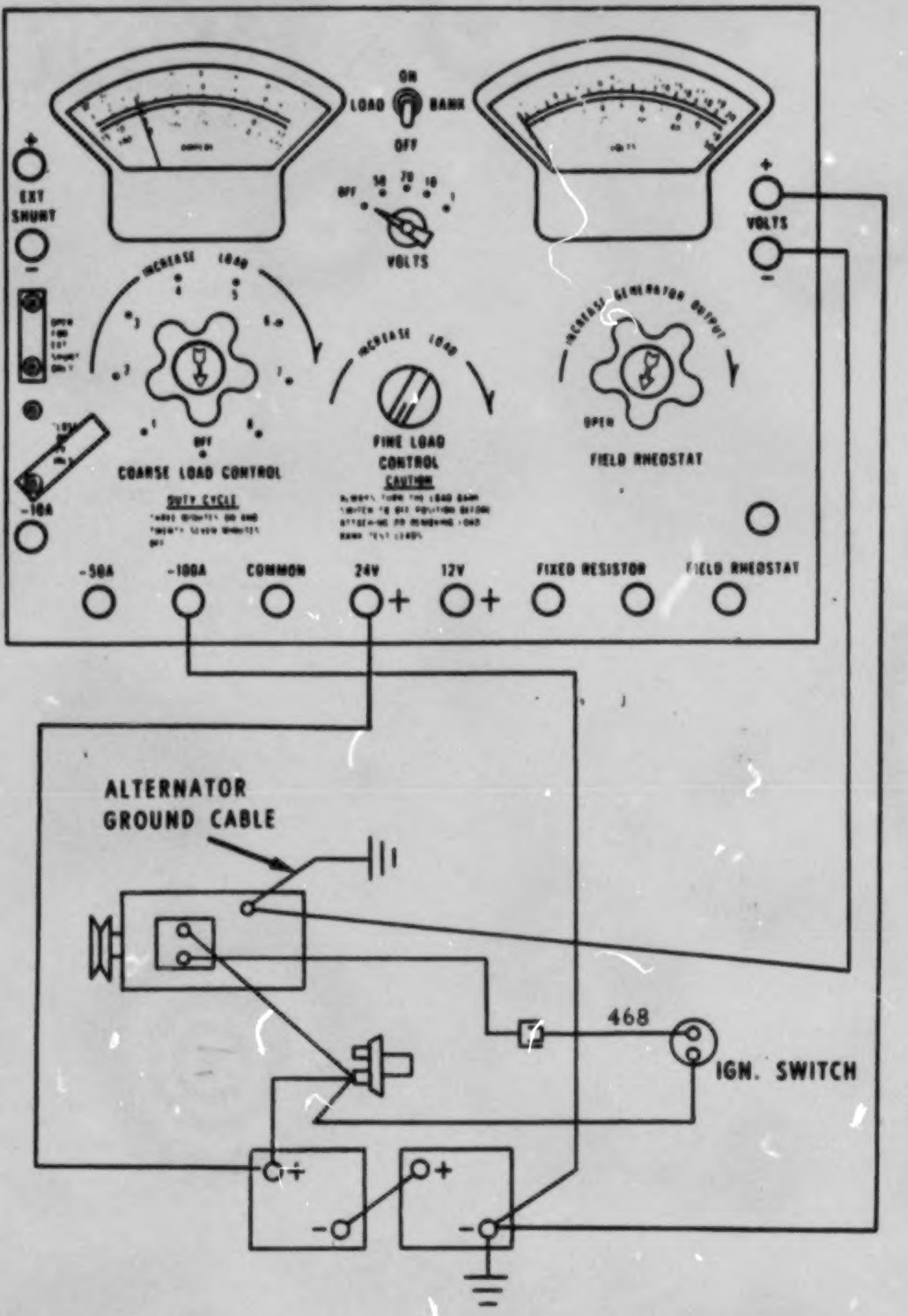


LOAD
ON
BANK
OFF
OFF
50
70
10
VOLTS
+
EXT SHUNT
−
−10A
INCREASE LOAD
COARSE LOAD CONTROL
OFF
DUTY CYCLE
INCREASE LOAD
FINE LOAD CONTROL
CAUTION
INCREASE GENERATOR OUTPUT
OPEN
FIELD RHEOSTAT
+
VOLTS
−
−50A
−100A
COMMON
24V
+
12V
+
FIXED RESISTOR
FIELD RHEOSTAT
ALTERNATOR GROUND CABLE
468
IGN. SWITCH
+
−
+
−

4-39

## 18. RECTIFIER INTEGRITY TEST (DIODE LEAKAGE TEST).

a. Purpose. To determine the serviceability of the diode rectifier assembly.

b. Hookup procedure.

Note. - Be sure that the ignition switch is turned off during this test.

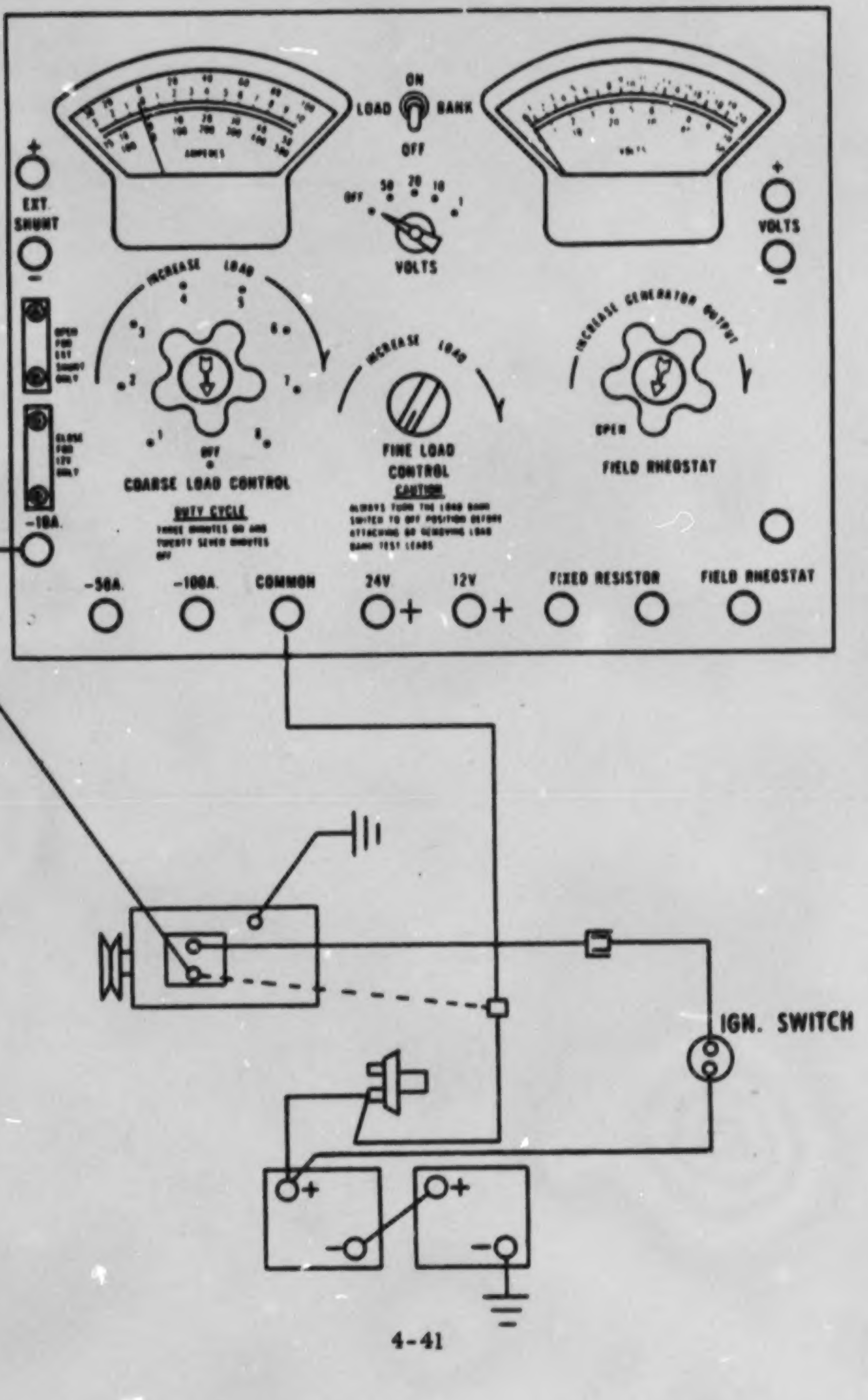
(1) Disconnect the alternator output cable from the alternator output terminal.

Note. - Disconnect battery ground cable or open master switch before connecting and disconnecting the alternator output lead.

(2) Connect one end of the positive ammeter lead to the common binding post of the LVCT and connect the other end to the alternator output cable that was disconnected.

(3) Connect one end of the negative ammeter lead to the -10-amp binding post of the LVCT and connect the other end to the alternator output terminal. Connect the battery ground cable.

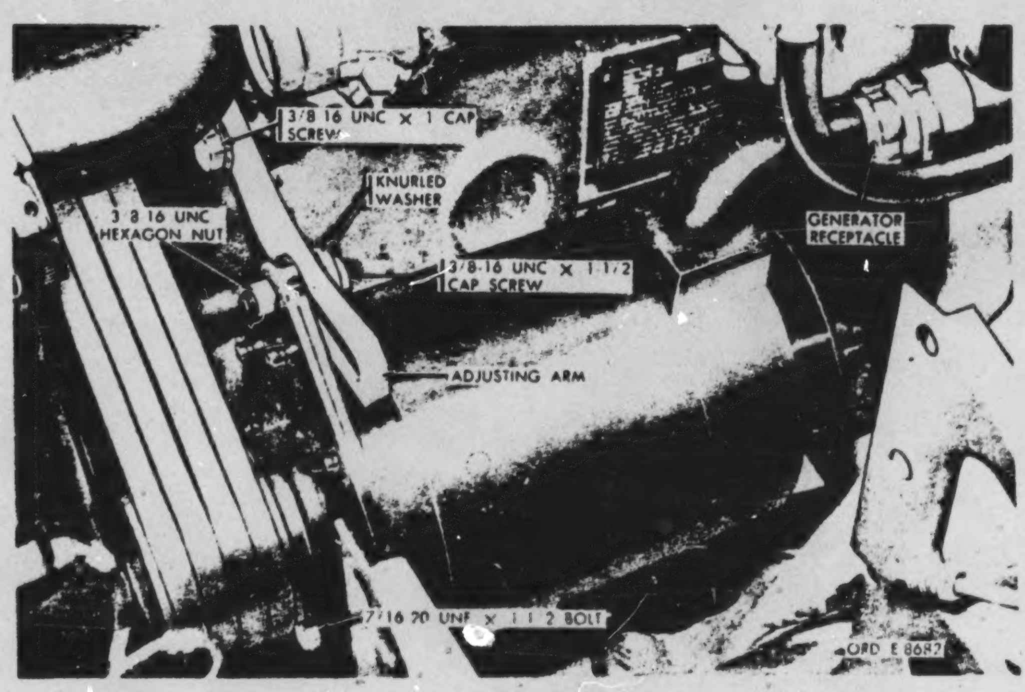
(4) There should be no indication on the ammeter except a small jump which may occur when the negative ammeter lead is connected. If there is an indication, one or more of the diodes in the rectifier are leaking and the alternator must be replaced.


ON
LOAD
BANK
OFF
AMPERES
VOLTS
OFF
50
20
10
1
VOLTS
+
EXT. SHUNT
−
VOLTS
+
−
OPEN FOR EXT SHUNT ONLY
CLOSE FOR 12V ONLY
INCREASE LOAD
1
2
3
4
5
6
7
8
OFF
COARSE LOAD CONTROL
DUTY CYCLE
THREE MINUTES ON AND TWENTY SEVEN MINUTES OFF
INCREASE LOAD
FINE LOAD CONTROL
CAUTION
ALWAYS TURN THE LOAD BANK SWITCH TO OFF POSITION BEFORE ATTACHING OR REMOVING LOAD BANK TEST LEADS
INCREASE GENERATOR OUTPUT
OPEN
FIELD RHEOSTAT
−10A.
−50A.
−100A.
COMMON
24V
12V
FIXED RESISTOR
FIELD RHEOSTAT
+
+
IGN. SWITCH
+
−
+
−

19. COMPONENT REMOVAL AND REPLACEMENT. If the inspection or tests show the alternator is faulty, it will have to be replaced. This will be one of your jobs. Listed below are the procedures for removing and replacing the 100-ampere alternator from the M151, 1/4-ton truck.

a. To remove the alternator assembly, first remove the air cleaner and carburetor air intake hose.

(1) Now, disconnect the generator to rectifier harness connector using a spanner wrench.


3/8 16 UNC X 1 CAP SCREW
KNURLED WASHER
3 8 16 UNC HEXAGON NUT
GENERATOR RECEPTACLE
3/8-16 UNC X 1 1/2 CAP SCREW
ADJUSTING ARM
7/16 20 UNF X 1 1 2 BOLT
ORD E 8682

(2) Next, loosen the generator to generator support attaching bolts. Then loosen the adjusting arm screw at the engine block and remove the generator adjusting arm screw, washer, and nut from the generator. Push the generator toward the engine block and remove the belts from the generator drive pulley.

(3) The next step is to remove the generator to support attaching bolts, washers, and nuts, and then lift out the generator assembly.

(4) You can now remove the nut and washer holding the generator drive pulley to the generator shaft.

(5) The pulley is removed from the shaft by using a suitable puller. You can remove the Woodruff key by driving it from the slot in the shaft.

b. When installing the alternator assembly, assemble the pulley to the rotor shaft with a Woodruff key, flat washer, and nut.

(1) Secure the pulley in a vise using wood blocks or brass jaws. Use a torque wrench and tighten the nut to 75-80 lb-ft. Position the generator, with pulley assembly, to the generator support.

(2) Secure the generator to the generator support using the two bolts, four flat washers, and the two safety nuts previously removed. Use one flat washer at each bolt head and another at each nut. Install both bolts with the heads toward the front of the vehicle and tighten them slightly. Final tightening will be done after the belts are installed.

(3) Attach the adjusting arm to the generator housing using the capscrew, knurled washer, and hexagon nut. Tighten the arm attaching screw and bolt at the engine block snugly but not to a final tight.

(4) Place the fan and generator belts in the pulley grooves. Pull the generator outward and tighten all mounting nuts and bolts. Check the belt tension by placing a straightedge or ruler on the belt between the water pump pulley and generator pulley. Push down firmly on this belt, the belt play should be approximately 1/2 inch from the straightedge or ruler. Loosen the necessary mounting bolts and re-adjust the generator if required. Check the other three belts. If any of the four belts differ in tension, replace all the belts, to make a matched set. Finally, tighten the bolts securing the adjusting arm to the engine block to 35-40 lb-ft torque.

(5) Install the air cleaner and carburetor air intake hose.

(6) Start the engine and check the operation of the generator by reading the battery-generator indicator mounted on the instrument panel. The indicator pointer should be in the upper portion of the orange block or lower portion of the green block at idle speed.

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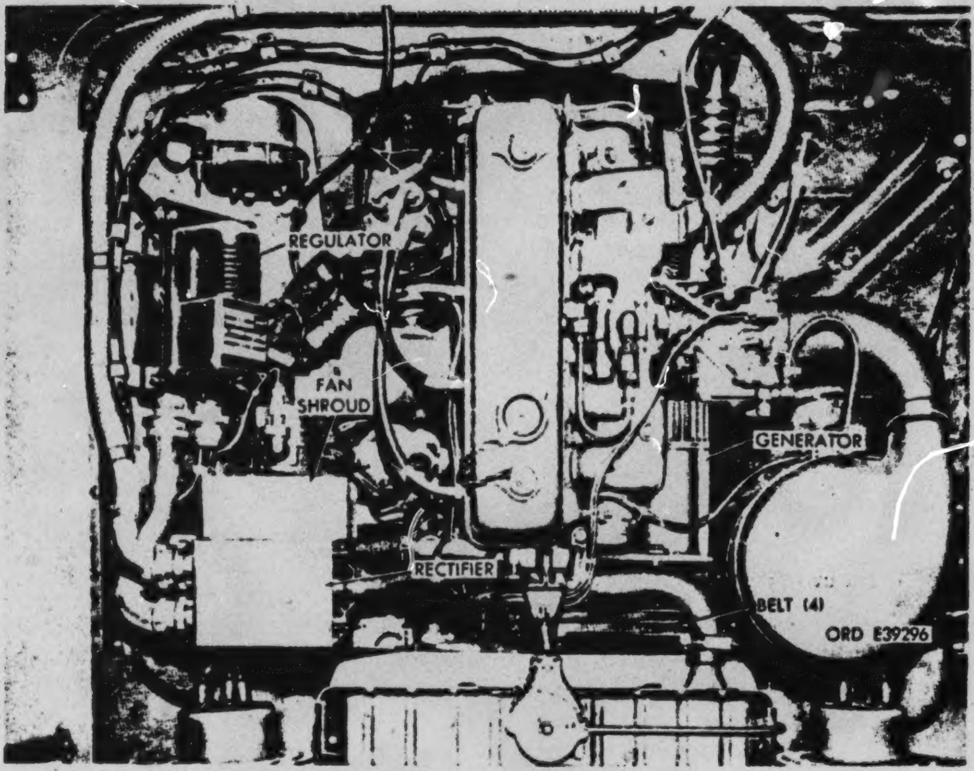
c. To remove the regulator assembly, disconnect the vehicle ground cable terminal at the battery post.

(1) Then disconnect the two cable connectors from the regulator using a spanner wrench.



(2) Next, remove the two nuts and cable clamps from the regulator shock mounting screws. Remove the generator ground wire on the right rear screw. Turn the cable clamps back out of the way and reinstall the two nuts to the regulator shock mounting screws.

(3) Now remove the four bolts holding the regulator assembly to the regulator and rectifier mounting bracket.

(4) Next, remove the regulator complete with its shock mounting from the regulator and rectifier mounting bracket. Also, remove the cable clamp and regulator ground wire from the regulator mounting right rear screw.

d. To install the regulator assembly, follow the procedures as listed.

(1) Connect the two cable connectors to the regulator. Place the regulator assembly on the mounting bracket with the receptacles facing forward. Secure the regulator to the bracket with the four screws and four internal teeth lockwashers that you removed. The short regulator ground wire is attached with the right rear screw together with a cable clamp. Tighten the screws to 6-8 lb-ft torque.

(2) Remove the two regulator right shock mounting nuts and place one cable on each stud. On the rear stud also install the regulator ground wire and external teeth lockwasher. Tighten the nuts to 11-12 lb-ft torque.

(3) Tighten the cable connectors to the receptacles using a spanner wrench.

(4) Then connect the cable to the ground post (terminal) of the battery, start the engine, and check the operation of the regulator by reading the generator-battery indicator on the instrument panel. The indicator pointer should be in the upper portion of the orange block or lower portion of the green block when the engine is operating at idle speed.

e. To remove the rectifier and fan assembly, first disconnect both cable connectors from the rectifier and one cable from the fan.

(1) Remove the two rectifiers to mounting bracket screws and washers. These screws are located near the rectifier mounting bolts (studs). Then loosen the rectifier mounting bolt nuts.

(2) Lift the rectifier with fan assembly from the mounting brackets. Remove the four self-tapping screws securing the fan shroud to the rectifier (two on each side). Then loosen the two lower screws.

(3) Next, remove the two roundhead screws securing the rectifier shroud to the rectifier. Tilt the rectifier assembly and remove the fan motor and shrouds from the rectifier as an assembly.

f. To install the rectifier assembly, first install the shroud and fan assembly on the rectifier using the four internal teeth lockwashers and the four tapping screws. Tighten the two lower fillister-head screws. Secure the rectifier shroud to the rectifier using the two panhead screws and two internal teeth lockwashers.

(1) Then install the complete rectifier assembly onto the rectifier mounting bracket with the receptacles facing the right side of the

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vehicle. Aline the rectifier to the mounting bracket holes and install the two self-tapping roundhead screws and internal teeth lockwashers to secure the rectifier to the mounting bracket holes. Install the two self-tapping roundhead screws and internal teeth lockwashers to secure the rectifier to the mounting bracket.

(2) Tighten the stud nuts to 10-22 lb-ft torque. The last thing to connect is the cable connectors to the rectifier and the cable to the fan motor.

(3) Now, turn the ignition switch to the on position and check to see if the fan operates on the rectifier and fan assembly. Start the engine and check the operation of the rectifier reading the generator-battery indicator on the instrument panel. The indicator pointer should be in the upper portion of the orange block or lower portion of the green block at idle speed.

Note. - Complete exercises number 72 through 80 before continuing to section III.

72. What is the main advantage of an AC generator (alternator) over a DC generator used in automotive vehicles?

    a. Less cost
    b. Higher output at low speeds
    c. Requires less power to operate

73. What supplies the magnetic field for the alternator used on wheeled vehicles?

    a. Stator
    b. Rotor
    c. Pole shoes

74. What type alternators are used on military wheeled vehicles?

    a. Single-phase
    b. Two-phase
    c. Three-phase

75. Which of the following is NOT used in the 100-ampere alternator regulator?

    a. Circuit breaker
    b. Load relay
    c. Adjusting rheostat

76. The solid state rectifiers used with the 60-ampere alternator are also called

a. load relays.
b. diodes.
c. carbon piles.

77. What type of voltage regulator is used with the 100-ampere AC generator?

a. Vibrator
b. Magnetic coil
c. Carbon pile

78. Which is the lowest maintenance level that is authorized to adjust the voltage on a 100-ampere alternator used on wheeled vehicles?

a. Organizational
b. Direct support
c. General support

79. The voltage regulators used to control both the AC and DC generators on military vehicles are set to limit the charging voltage to about

a. 12 volts.
b. 24 volts.
c. 28 volts.

80. Which should be removed before removing the alternator on an M151 1/4-ton truck?

a. Air cleaner
b. Regulator
c. Oil filter

## SECTION III. CONCLUSION

20. **SUMMARY.** In this lesson we have covered the construction and operation of the components of AC and DC charging systems. We also covered the tests you will be required to make on the systems and the procedures for removing and replacing the components.

21. **PRACTICE TASK LIST DIRECTIONS.** Appendix A contains a list of tasks associated with wheeled vehicle generating systems. They are representative of the tasks you will be required to perform as a wheeled vehicle repairman. Perform all of the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

## APPENDIX A

## PRACTICE TASK LIST

Practice Objectives. After practicing the following tasks you will be able to:

1. Inspect the charging systems of wheeled vehicles.
2. Test the components of wheeled vehicle charging systems.
3. Evaluate the results of the tests.

Tasks.

1. In this lesson we covered the construction, operation, inspection, and testing of charging systems. So that you will understand and remember these things you should practice the tasks listed below. Use the vehicles in your company for this.

a. Inspect the charging system of the M151, 1/4-ton truck.

(1) Check the wiring harnesses and connections between the generator or alternator and the batteries.

(2) Check the regulator mounting bolts.

(3) Check the drive belt tension.

b. If the charging system uses an alternator, in addition to the above check the following items:

(1) Check the rectifier mounting bolts, shield, and cooling fan (100-ampere alternator only).

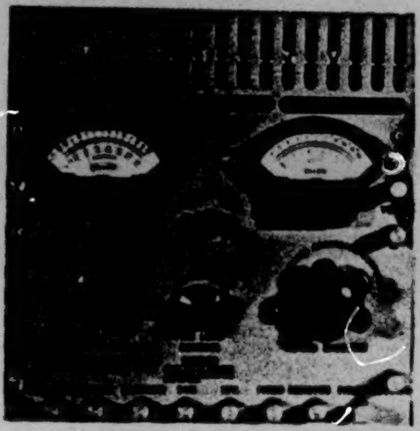
(2) Check for dirt on the rectifier (100-ampere alternator) and on the cooling fins (60-ampere alternator).

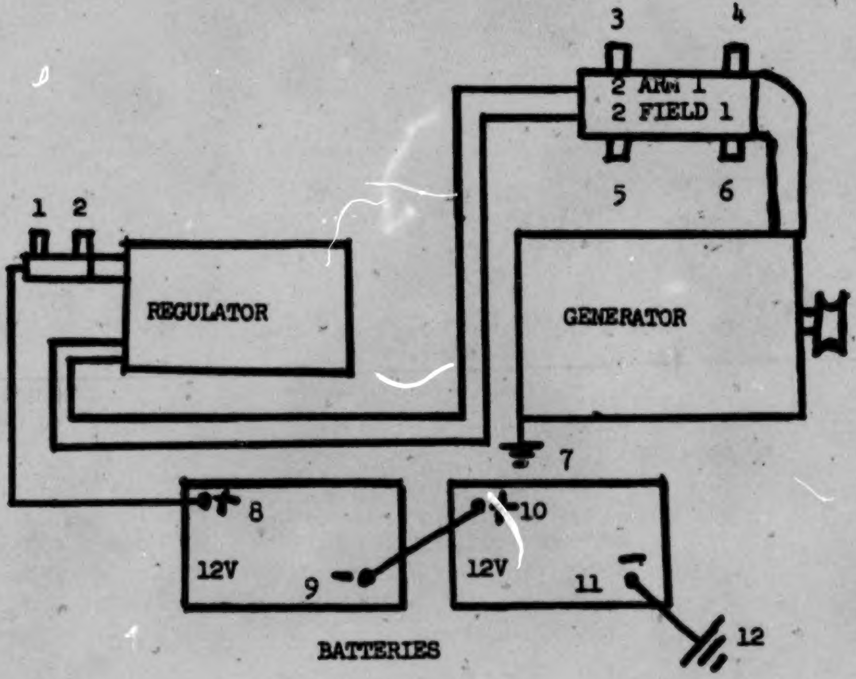
2. Another thing you should practice is the use of the LVCT in checking the charging system. Before making these checks, review the procedures given in this lesson, the manufacturer's pamphlet, and the vehicle TM.

a. When you feel that you know the proper way to connect the meters, go to the following schematics and draw in the leads as they should be connected to make the test. Check your work for accuracy by referring to the appropriate paragraphs and illustrations in this lesson.

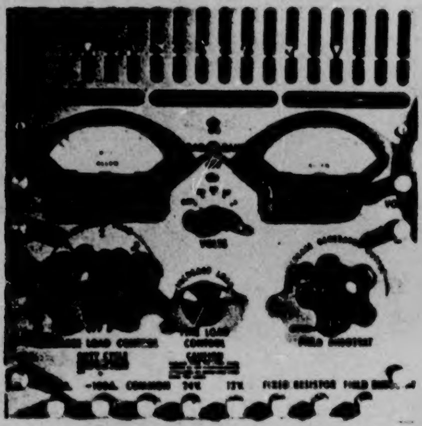
b. In the schematics, the links on the adapters are not shown. If the links should be closed on the test, draw a line to show that the link is closed. For example, if the links on the regulator adapter should be closed, draw a line connecting terminals 1 and 2.

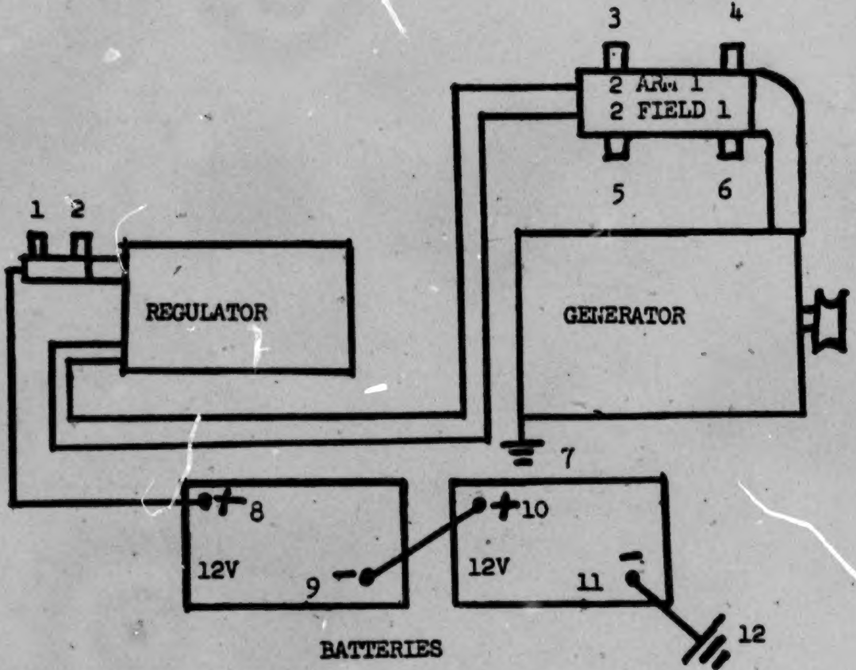
(1) Draw in the meter leads as they should be connected when making a generator output test.



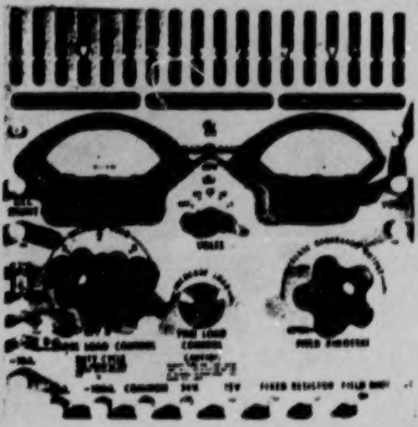

3
4
2 ARM 1
2 FIELD 1
5
6
1
2
REGULATOR
GENERATOR
7
8
12V
9
10
12V
11
12
BATTERIES

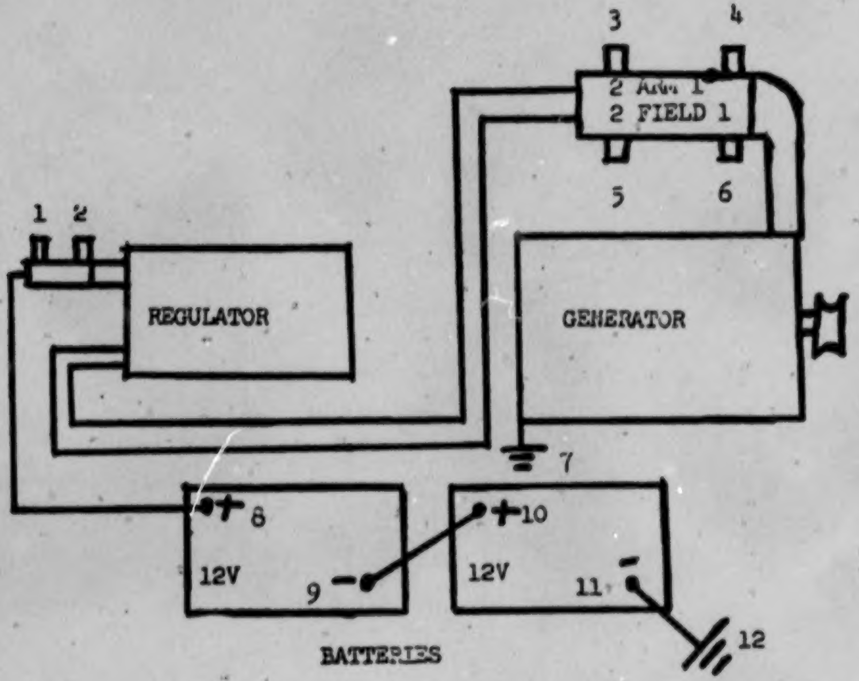
(2) Draw in the meter leads as they should be connected when making a cutout relay test.



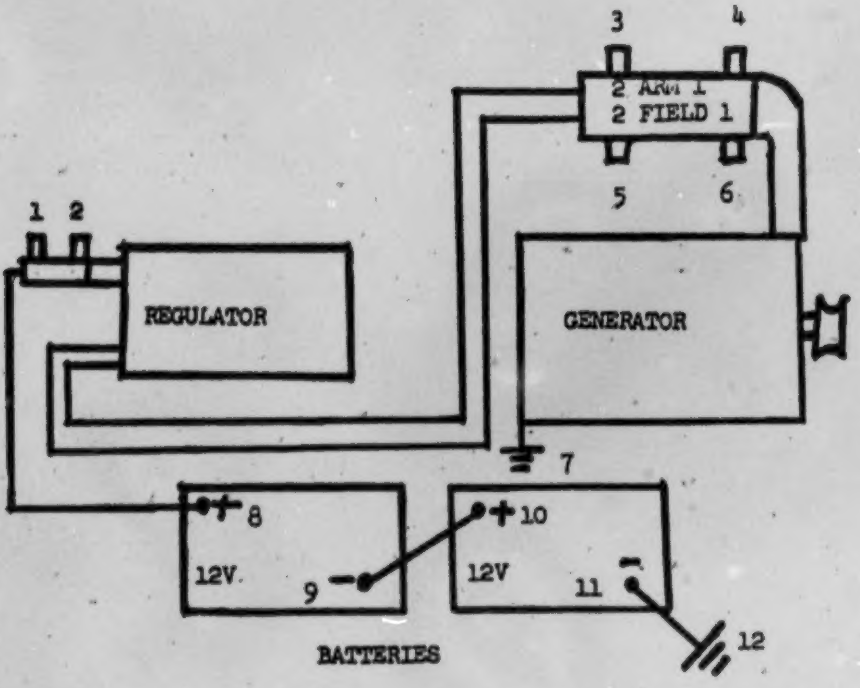

3
4
2 ARM 1
2 FIELD 1
5
6
1
2
REGULATOR
GENERATOR
7
8
12V
9
10
12V
11
12
BATTERIES

(3) Draw in the meter leads as they should be connected to make a voltage regulator test.




3
4
2 ARM 1
2 FIELD 1
5
6
1
2
REGULATOR
GENERATOR
7
+ 8
12V
9 −
+ 10
12V
11 −
12
BATTERIES

(4) Draw in the meter leads as they should be connected to make a current regulator test.


3
4
2 ARM 1
2 FIELD 1
5
6
1
2
REGULATOR
GENERATOR
7
+ 8
12V.
9 −
+ 10
12V
11 −
12
BATTERIES

3. You should now be ready to make a few tests on the vehicle. Before connecting the leads of the LVCT to the vehicle, disconnect the battery ground cable. When the leads are connected, check them over to see if you have made a mistake. When you think they are right, check them again, be sure they are right, then reconnect the battery ground cable and make the test.

a. Test the DC generator and regulator of the M151, 1/4-ton truck and evaluate the results.

(1) Perform a generator output test.

(2) Perform a circuit breaker (cutout relay) test.

(3) Perform a voltage regulator test.

(4) Perform a current regulator test.

b. Perform a voltage output test on an alternator, this can be done using the LVCT.

4. You will be required to remove and replace charging system components. If you get the chance, work with another repairman who is doing this. If not, you can at least look at the system and see just what will have to be done. Here is one example of component removal and replacement.

a. Remove and replace the DC generator from the M151, 1/4-ton truck.

(1) Remove the vent lines and hoses from the air cleaner and remove the air cleaner.

(2) Remove the generator to regulator cable.

(3) Loosen the drive belts and remove the generator.

(4) Replace the generator using the reverse of the above procedures.

(5) Adjust the drive belts.

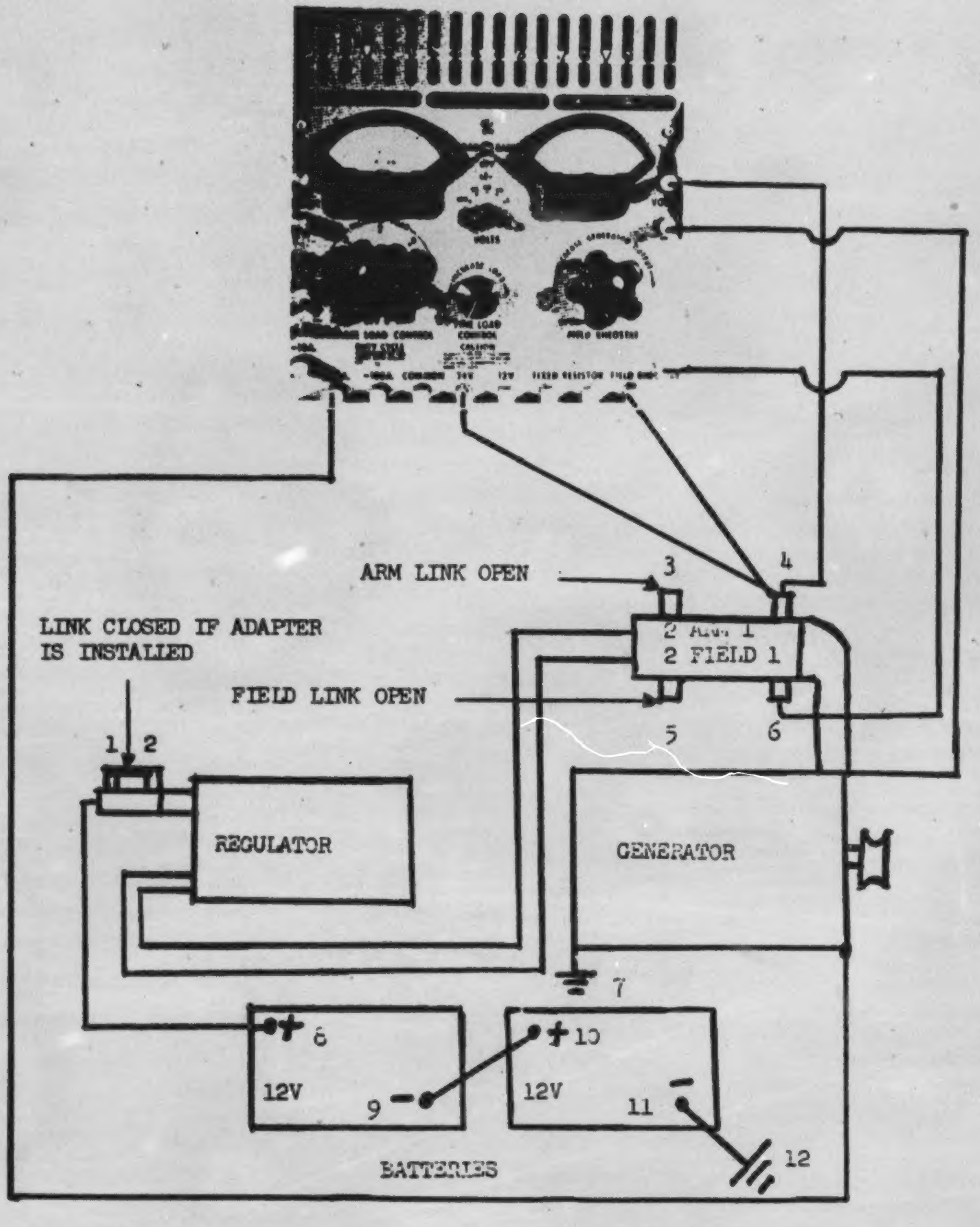
b. If the vehicle is equipped with an alternator, the procedures are almost the same as for the DC generator.

## APPENDIX B

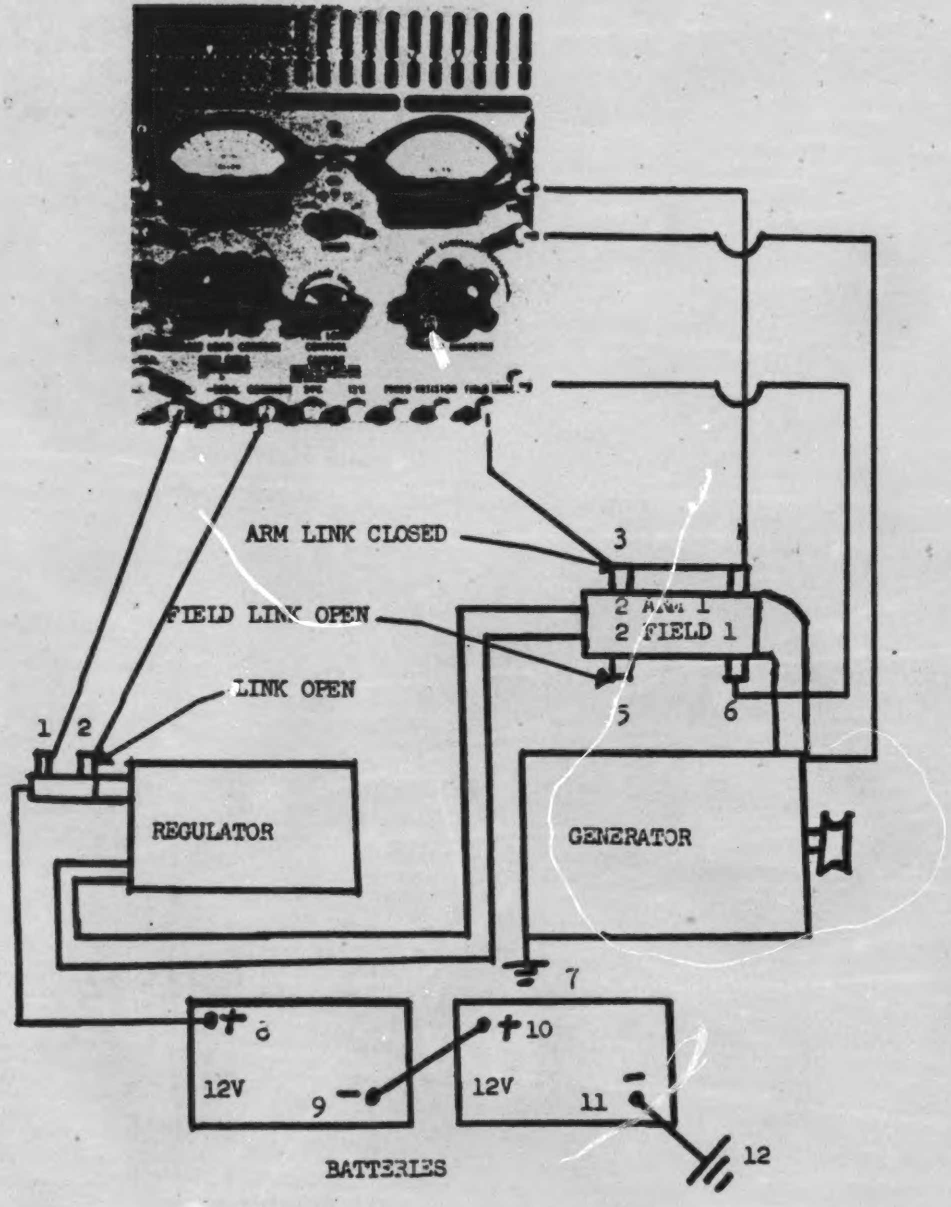
## REFERENCES

| | | |
|---|---|---|
| TM 9-8000 | Principles of Automotive Vehicles | Jan 56 |

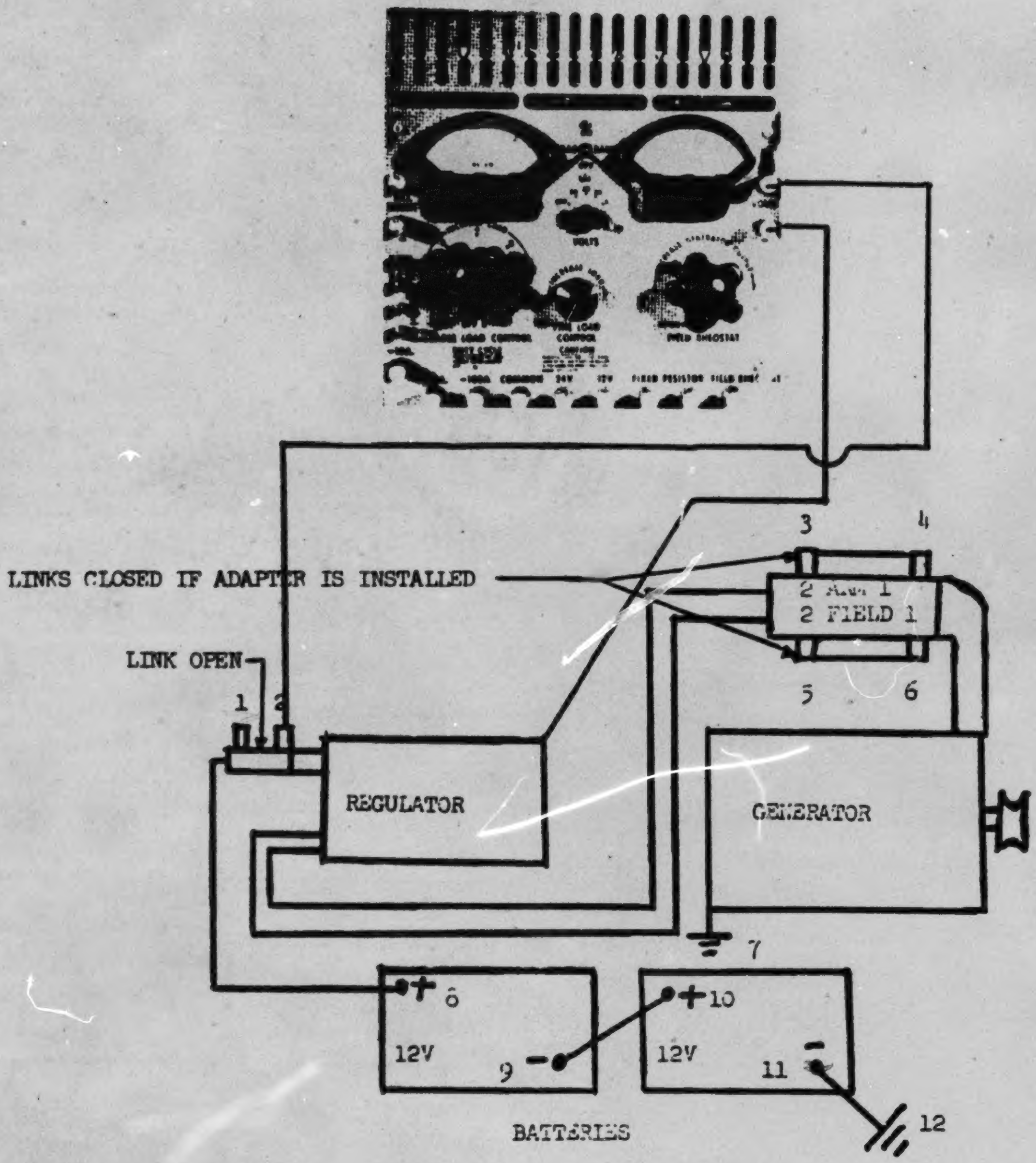
★ U. S. GOVERNMENT PRINTING OFFICE: 1974—620-215/2760 2-1


ARM LINK OPEN
3
4
LINK CLOSED IF ADAPTER
IS INSTALLED
2 ARM 1
2 FIELD 1
FIELD LINK OPEN
5
6
1
2
REGULATOR
GENERATOR
7
+ 8
+ 10
12V
9 −
12V
11 −
12
BATTERIES

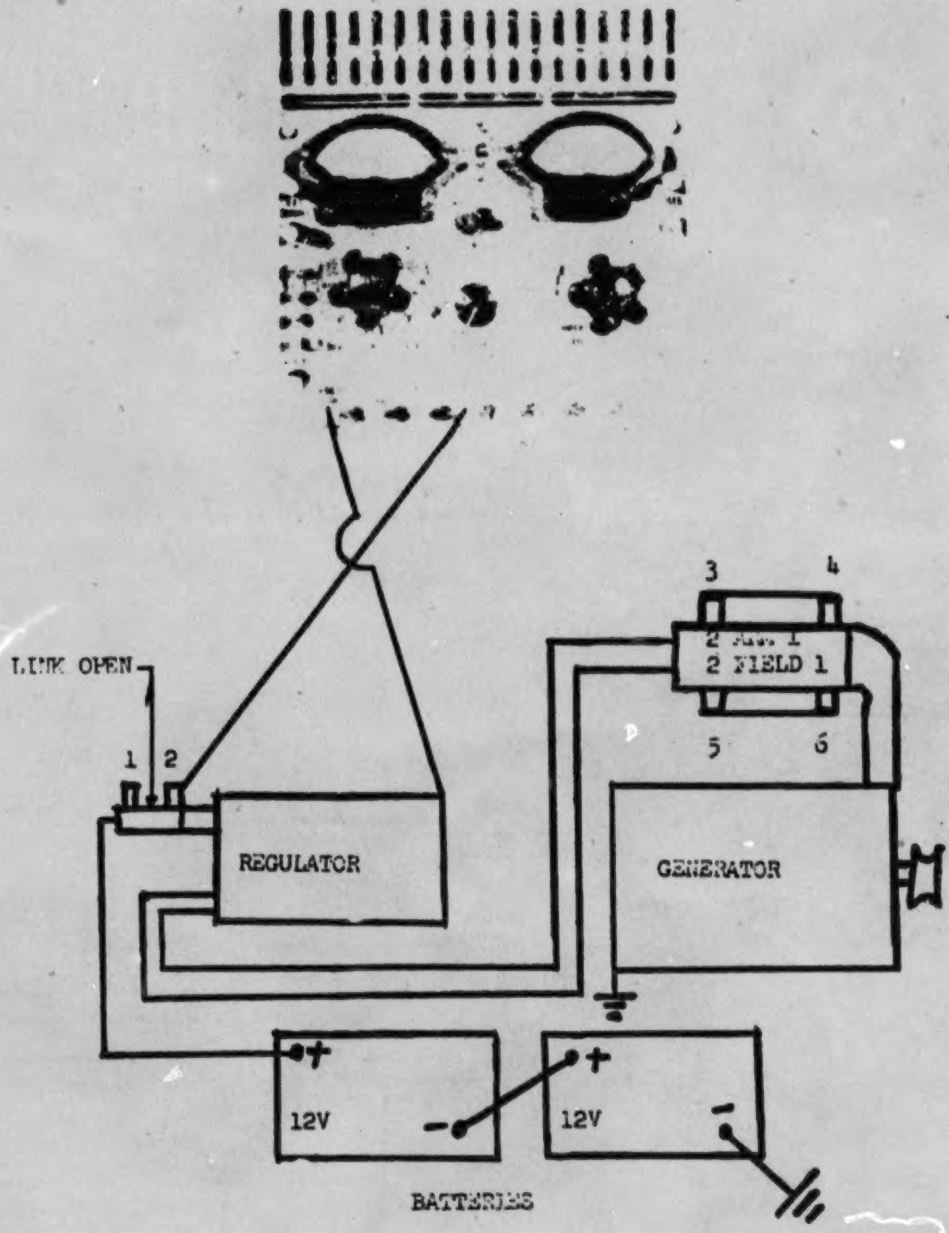
Foldout illustration No 1. Generator output test.


ARM LINK CLOSED
FIELD LINK OPEN
LINK OPEN
1
2
3
4
2 ARM 1
2 FIELD 1
5
6
REGULATOR
GENERATOR
7
+ 8
+ 10
12V
9 −
12V
− 11
12
BATTERIES

Foldout illustration No 2. Circuit breaker (cutout relay) test.


VOLTS
FINE LOAD CONTROL
FIELD RHEOSTAT
LINKS CLOSED IF ADAPTER IS INSTALLED
LINK OPEN
1
2
3
4
2 ARM 1
2 FIELD 1
5
6
REGULATOR
GENERATOR
7
+ 8
12V
9 −
+ 10
12V
11 −
12
BATTERIES

Foldout illustration No 3. Voltage regulator test.


LINK OPEN
1
2
REGULATOR
3
4
2 ARM 1
2 FIELD 1
5
6
GENERATOR
+
12V
-
+
12V
-
BATTERIES

Foldout illustration No 4. Current regulator test.

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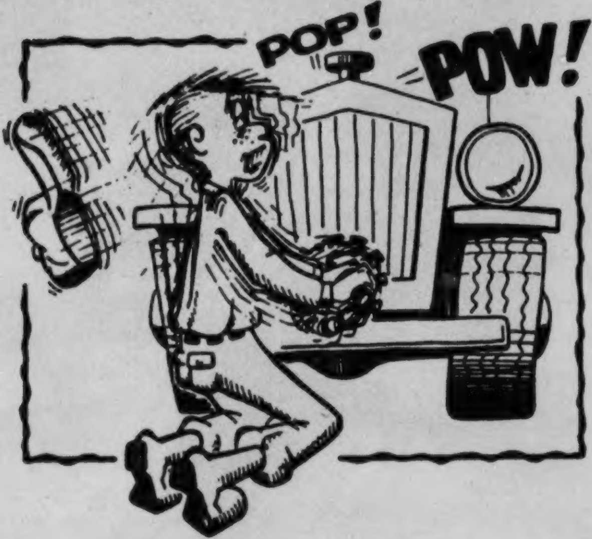
ENLISTED MOS

CORRESPONDENCE/OJT COURSE

# ORDNANCE SUBCOURSE 63B203



## LESSON 5
## CRANKING SYSTEMS

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

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# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

**Ordnance Subcourse** 63B203 . . . . Wheeled Vehicle Electrical Systems

**Lesson** 5. . . . . . . . . . . . . . . Cranking Systems

**Credit Hours** . . . . . . . . . . . Three

**Lesson Objective** . . . . . . . . . After studying this lesson you will be able to:

1. State the purpose of the cranking motor.
2. Explain cranking motor principles and operation.
3. Describe cranking motor construction.
4. Describe starter drive construction.
5. Explain starter drive operation.
6. Describe the procedures for checking the batteries.

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7. Describe the procedures for making a ground loss test.

8. Describe the procedures for making a cable and starter switch test.

9. Describe the procedures for making a starter current draw test.

10. Describe the procedures for starter removal and replacement.

**Study Assignment** . . . . . . . . . . Study the text carefully. It will provide you with the knowledge you will need to maintain cranking systems. It will cover operation, construction, testing, removing, and replacing cranking system components.

**Materials Required** . . . . . . . . All students: Exercise response list and answer sheet.
Correspondence/OJT option students: See appendix A.

**Suggestions** . . . . . . . . . . . . . Study the text and illustrations carefully. After studying this lesson you should understand all aspects and important features of wheeled vehicle cranking systems.

## STUDY TEXT

## SECTION I. CONSTRUCTION AND OPERATION OF CRANKING MOTORS

1. INTRODUCTION. The automotive electrical system includes a starter motor which has replaced the handcrank used to start cars in bygone days. The purpose of the starter (also called cranking) motor is to rotate the engine crankshaft so the engine can start and begin to operate under its own power. The starter motor is a low-resistance, direct current motor producing a high torque. It draws the current directly from the battery.

2. PURPOSE OF CRANKING MOTORS. Motors, like generators, are simply a means of changing energy from one form to another. In a generator we take the mechanical energy of the turning pulley and change it to electrical energy. A cranking motor does just the opposite of the generator. Electrical energy sent to the motor is changed to mechanical energy to crank the engine. A practical motor must produce continuous rotary motion. In addition, it must develop a twisting or turning force called torque. In this lesson we shall see how the starter motor develops torque and how it is used to crank the engine.

3. PRINCIPLES OF MOTORS. The magnetic principle of attraction and repulsion, or unlike poles attract and like poles repel, is the principle applied in the development of the electric motor. Remember that a wire carrying an electric current produces a magnetic field. When this wire is placed in the magnetic field of another magnet, mechanical motion is produced because the magnetic field around the wire is repulsed (pushed away) by the field around the other magnet.

a. To understand how mechanical motion is produced by magnetic repulsion, study the actions in the foldout in the back of this lesson. Notice the lines of force in the top picture. They are moving from the north pole to the south pole and are traveling in almost straight lines. In fact the lines would be straight if the ends of the magnets were flat instead of curved. The magnetic lines of force moving between the north pole and the south pole of any magnet always take the easiest path or route. The easiest path between the two poles is usually a straight line because a straight line is also the shortest path.

b. Remember, each of the magnetic lines of force move parallel (side by side) to the other lines of force. They will not cross each other.

c. The lines of force act a lot like rubberbands. If you stretch the bands between two pegs, they tend to straighten out. Push down on the stretched rubberbands with your finger. If the bands are stretched tight

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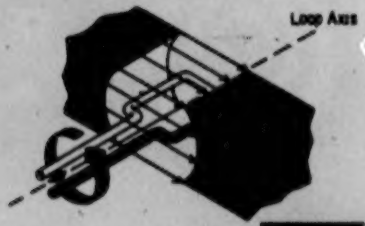
you can feel them pushing back against your finger. Now move your finger away quickly. The rubberbands will snap back to form straight lines again. Think of the magnetic lines of force between the two poles of a magnet acting the same way as do the stretched bands.

d. In B of the foldout the lines of force around a current carrying conductor (wire) are illustrated. The + symbol on the end of the wire means the current is flowing away from you as you view the wire. With the current flowing in that direction, the lines of force in the magnetic field around the wire are moving counterclockwise (note the arrows on the lines of force). If the current is flowing toward you as you view the wire (notice the dot in the center of the wire in D of the foldout), the lines of force would be moving clockwise. In other words, the polarity would be reversed.

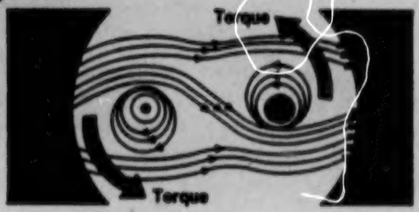
e. If a current carrying wire is placed in a magnetic field as in C of the foldout, notice what happens to the lines of force that are moving from the north pole to the south pole of the magnet. They are forced to bend just as the stretched rubberbands were forced to bend when you pressed on them with your finger. The lines of force traveling from north to south bend down in this case because they are pushed downward by the counterclockwise rotation of the lines of force around the current carrying wire. Because the lines of force from the north to south pole pieces of the magnet try to straighten out like the rubberbands, they force the current carrying wire up (note the arrow). In D of the foldout, the current is moving in the opposite direction in the wire and the magnet's lines of force push down on this wire. Both C and D of the foldout are good examples of magnetic repulsion (like poles pushing away from each other).

f. In the starter motor, like the generator, increasing the strength of the pole shoes will increase the number of lines of force. Likewise, increasing the current flow through the wire will increase the strength of the magnetic field around the wire. When these magnetic forces oppose each other, as in views C and D of the foldout, they try to push each other away. The opposing forces can be very great if the wire is carrying enough current to make the magnetic field very strong.

g. Now, let's bend a wire to form a loop and, place the loop in a magnetic field as shown here. Nothing happens until we send current through the loop. If we send current flowing through the loop in the direction shown, the magnet's lines of force push up on the right side of the loop and down on the left side. This produces the torque to rotate the entire loop counterclockwise (to the left). Actually, the loop would probably move only 1/4 of a revolution (90°) because it would be out of the magnetic field of the magnet. The loop would then be straight up and down instead of straight across as shown.

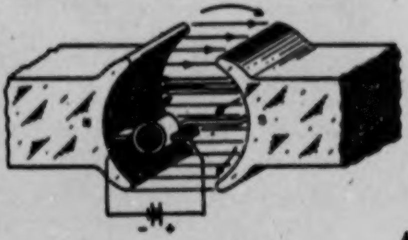


If, instead of a straight wire conductor, a loop is put in a magnetic field and current is passed through it, the newly created magnetic field interacts with the existing field to produce torque

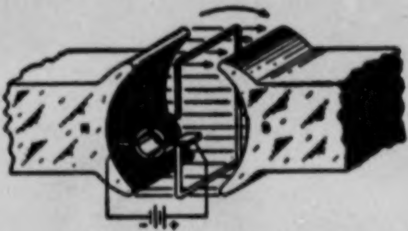


Torque is a twisting or turning force exerted on the loop that causes it to rotate around its axis. The direction of current going away from you is shown by an ⊗, and coming toward you by a ⊙

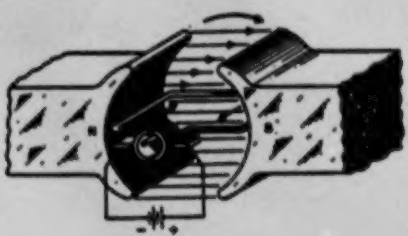
h. To get continuous rotation we need a magnetic field large enough to contain the loop. We would also need commutator bars and brushes like we had in the generator.



A



B



C

i. Notice that here we have added commutator bars and a larger field. In view A the left half of the loop is shown in black with an arrow to show the current is flowing from its commutator bar to the loop. The right side loop is pictured in white with an arrow showing the current flowing from it to its commutator bar. With battery current supplied through the brushes to the commutator bars, the loop would be forced to rotate clockwise. When the loop reaches and just passes the position shown in view B, look what happens. The commutator bar for the black half of the loop is now in contact with the positive (+) brush. The commutator bar connected to the white half of the loop is now in contact with the negative (-) brush. We have reversed

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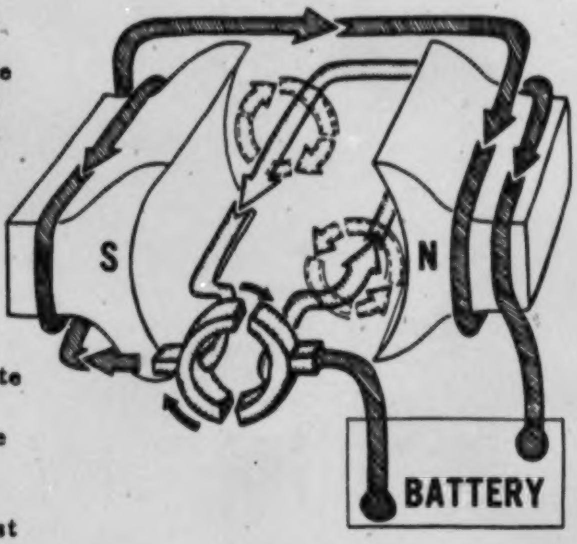
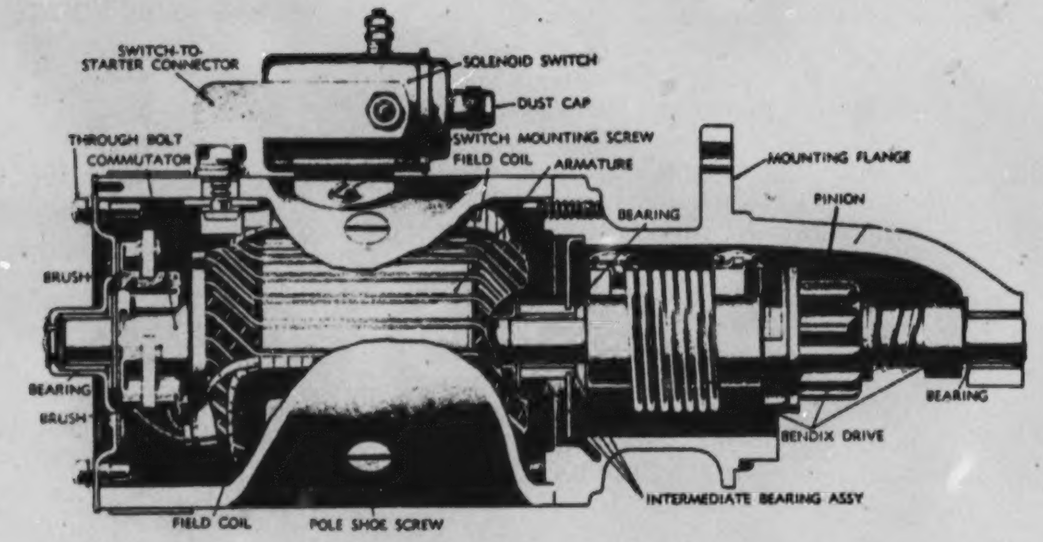
polarity in the loop and it will continue to rotate clockwise. When it rotates another 1/2 turn (180°) it will again reverse polarity and continue to rotate clockwise.

j. Of course a single loop would not produce enough torque to crank the engine. But, by using many loops, each with its own commutator bars, we can have a cranking motor that will produce all of the torque needed.

k. Most starter motors are series motors. They are called series motors because the rotating loop and the windings around the magnetic poles are connected in one (series) path. The current flowing through the loop also flows through the windings. In an actual motor, the windings around the pole shoes are called field windings because they help produce the magnetic field. The purpose of the field winding is to produce a strong magnetic field so that the loop will receive a more powerful push. Note that the poles are curved. They are curved so the conductors of the loop can pass as close as possible to the poles as they move past. Since the magnetic field is strongest near the poles, the conductors in the loops are given a stronger push.



l. In an actual cranking motor, there are many rotating loops all assembled into an armature. The armature consists of a shaft on which are mounted a laminated iron core and commutator. The loops, or windings, of the armature are mounted in the core and are insulated from one another and from the core. The commutator segments have riser bars, like the generator, to which the ends of the armature windings are connected by soldering.

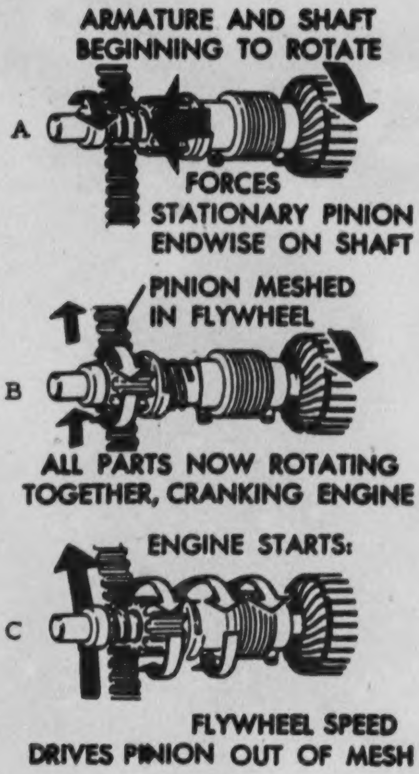

SWITCH-TO-STARTER CONNECTOR
SOLENOID SWITCH
DUST CAP
THROUGH BOLT
COMMUTATOR
SWITCH MOUNTING SCREW
FIELD COIL
ARMATURE
MOUNTING FLANGE
BEARING
PINION
BRUSH
BEARING
BRUSH
BEARING
BENDIX DRIVE
INTERMEDIATE BEARING ASSY
FIELD COIL
POLE SHOE SCREW

4. CRANKING MOTOR CONSTRUCTION. The vehicle cranking motor has only one job to do. That is to turn the crankshaft at a speed fast enough to start the engine. Since there are many different types and sizes of engines, there are many types and sizes of cranking motors. The common starter motor used on military vehicles consists of the following five main assemblies: armature, field and frame, commutator-end head, drive-end housing, and drive mechanism. The field windings, frame, and armature are almost the same as in the generator which you have already studied, except that in the starter motor the windings are much heavier in order to carry a lot of current. The commutator-end head houses the brush holders, brushes, and a bearing. The drive-end houses the drive mechanism and usually the mounting flange to mount the starter to the engine.

5. STARTER DRIVES. The starter usually drives the engine through a pinion (small) gear mounted on the starter motor armature shaft. When the starter motor is running, the pinion gear engages (meshes) with a large gear mounted on the rim of the engine flywheel.

a. Two types of starter drive mechanisms are in common use. These are the Bendix drive and the over-running clutch drive.

b. The Bendix drive consists of a threaded sleeve, which is fastened to the armature shaft by means of a drive spring, and a drive pinion which is threaded on the sleeve. The pinion has a weight on one side to make it unbalanced. Think of the sleeve as a bolt and the pinion as a nut threaded to the bolt. A weight is attached to the nut. If we spin the bolt, the nut, because of the weight, tries to stand still. However, the spinning bolt would force the nut to move forward or backward on its threads, depending on which way the bolt was spinning.

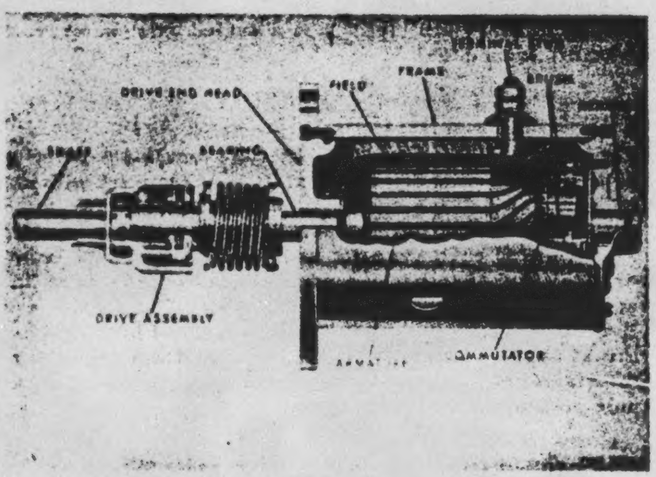

ARMATURE AND SHAFT BEGINNING TO ROTATE
A
FORCES STATIONARY PINION ENDWISE ON SHAFT
PINION MESHED IN FLYWHEEL
B
ALL PARTS NOW ROTATING TOGETHER, CRANKING ENGINE
ENGINE STARTS:
C
FLYWHEEL SPEED DRIVES PINION OUT OF MESH

(1) Now look at A of the above figure. The armature has started to turn and the pinion, which is not turning because of the weight on one side, is moving toward the flywheel ring gear. In view B the teeth on the pinion gear have meshed (engaged) with the teeth on the ring gear. The pinion has reached its stop and cannot move any further on the threaded sleeve. It is now locked to the sleeve and must turn with it. The now rotating pinion turns the flywheel gear, which in turn rotates the flywheel ring gear and engine crankshaft.

(2) As soon as the engine starts its speed of rotation is faster than that of the pinion. The ring gear now drives the pinion because it is turning faster. The pinion then moves back on the threaded sleeve and disengages from the ring gear.

(3) Sometimes the engine starts but fails to continue to run. However, the few turns that it does run may be enough to force the Bendix drive pinion out of mesh. To keep this from happening a new type of Bendix drive is used on some late model vehicles.

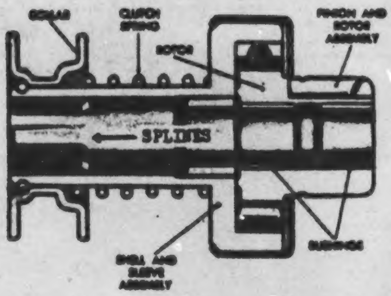
(4) This drive, called the Bendix Folo-Thru, is illustrated in this figure. Inside the drive is a spring-loaded pin. When the pinion moves to engage the flywheel gear, the pin enters a notch on the threaded sleeve to hold the pinion in mesh. As long as the engine turns slowly the pinion will be held in mesh with the flywheel by the pin in the notch on the sleeve. After the engine starts and is operating at a speed of about 400 RPM, the pinion, which is now spinning at a rate of several thousand RPM, will force the pin out of the notch on the sleeve. Then the pinion can move back on the threaded sleeve away from the flywheel.


DRIVE END HEAD
FIELD
FRAME
SHAFT
BEARING
DRIVE ASSEMBLY
OMMUTATOR

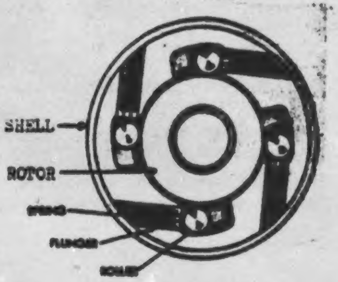
c. In the over-running clutch type of starter drive, the pinion is shifted into engagement with the flywheel with a lever.

(1) The drive for the over-running clutch has internal (inside) splines which fit external splines on the starter armature shaft. The drive pinion is attached to a rotor which forms the inner half of the over-running clutch.

SIDE VIEW


COLLAR
CLUTCH SPRING
ROTOR
PINION AND ROTOR ASSEMBLY
SPLINES
BUSHINGS
SHELL AND SLEEVE ASSEMBLY

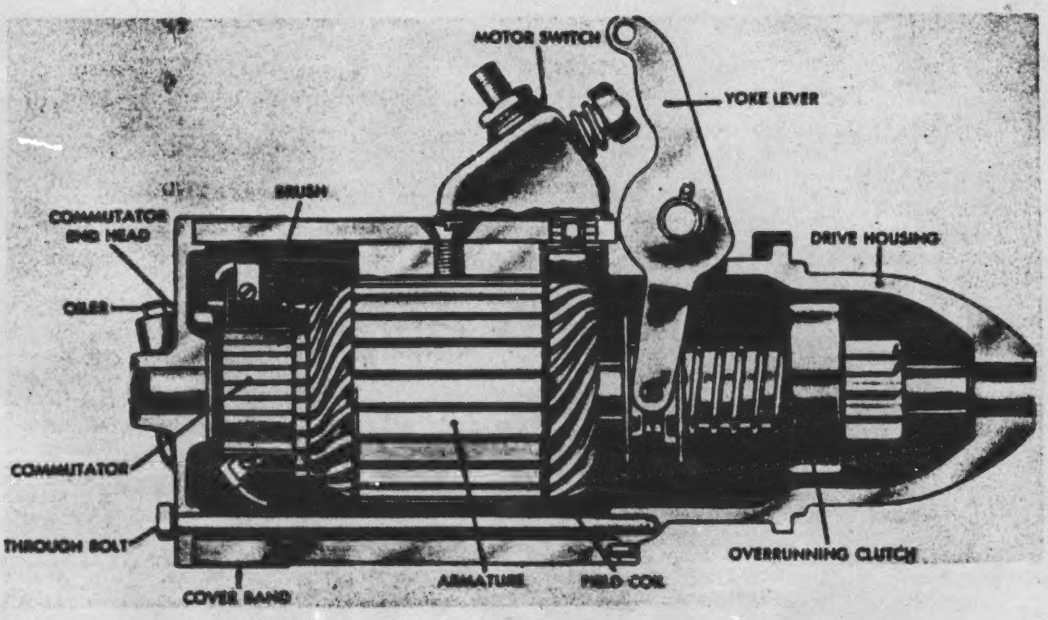
END VIEW


SHELL
ROTOR
SPRING
PLUNGER
ROLLER

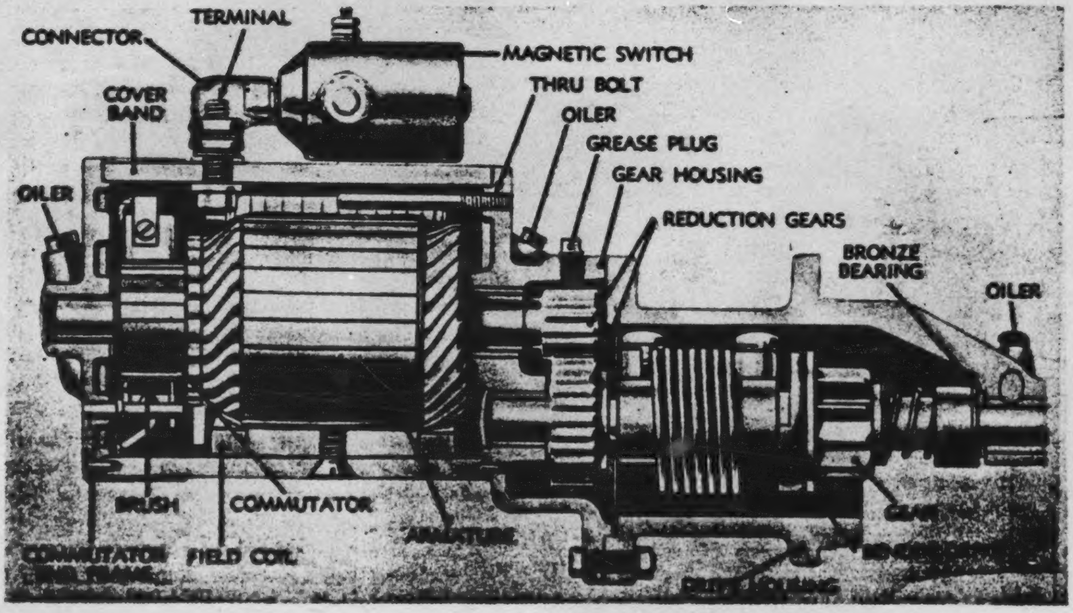
(2) Now look at the end view of the over-running clutch, which is really a one-way clutch. It can drive in one direction, but not the other. The outer shell is part of the splined sleeve, so it rotates when the starter armature rotates. The only connection between the shell and the rotor are the four spring-loaded rollers between them. Notice the rollers are in slots in the sleeve. They can move back and forth in the slots. The slots are tapered slightly. When the sleeve starts to rotate the rollers move in their tapered slots to a point where they become wedged (jammed) between the sleeve and the rotor.. Then the whole clutch turns as a single unit. When the engine cranks, the rollers are forced to move the other way in their slots, because the pinion and rotor are now traveling faster than the over-running clutch sleeve.

(3) You can easily test the action of the clutch by gripping the sleeve with one hand and the pinion with the other. Try to turn the pinion in either direction. You will find you can turn it one way, but when you try to turn it the opposite way, it locks. In fact, if you can turn it both ways it is defective and must be replaced.

(4) A shift lever (also called a yoke lever) is used with the over-running clutch to shift the starter pinion into mesh with the flywheel gear. The lever may be operated manually through linkage or by an electromagnet.

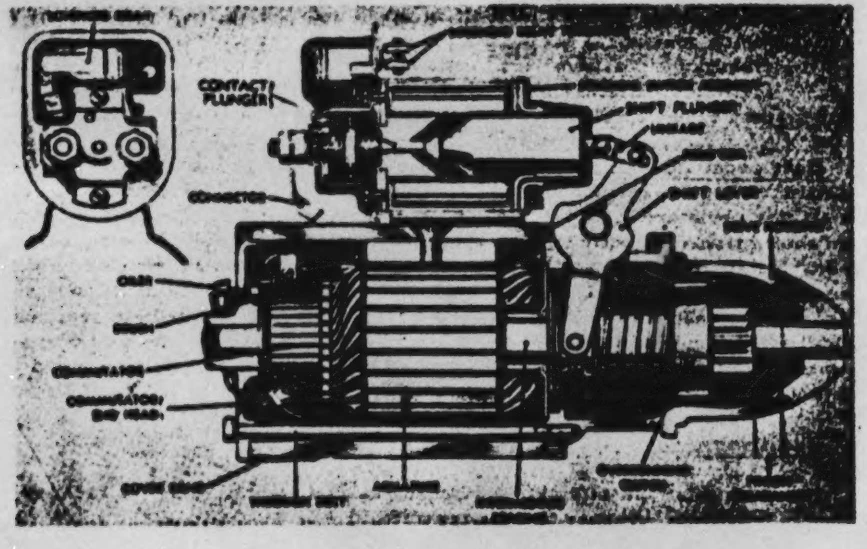

MOTOR SWITCH
YOKE LEVER
BRUSH
COMMUTATOR END HEAD
OILER
DRIVE HOUSING
COMMUTATOR
THROUGH BOLT
OVERRUNNING CLUTCH
COVER BAND
ARMATURE
FIELD COIL

d. The gear reduction obtained by having a small starter pinion gear drive the large flywheel gear is usually about 12 to 1 or more. This means the rotational speed of the starter armature is about 12 times that of the flywheel when the engine is being cranked. The pinion gear on the armature shaft meshes directly with the gear teeth on the flywheel. In some instances, however, a double reduction is needed. Here the final gear ratio may be as high as 25 to 1 or even 40 to 1. With double reduction the gear on the armature shaft does not mesh directly with the teeth on the flywheel, instead they mesh with an intermediate gear that drives the flywheel driving pinion. This double reduction drive permits the use of a small starter motor to turn a fairly large engine.

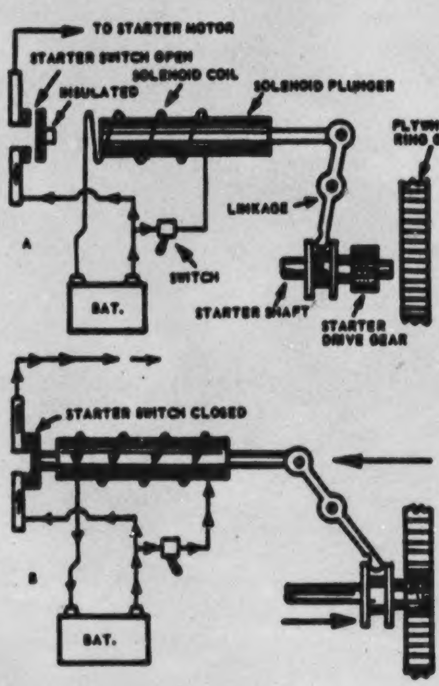

TERMINAL
CONNECTOR
MAGNETIC SWITCH
THRU BOLT
COVER BAND
OILER
GREASE PLUG
GEAR HOUSING
OILER
REDUCTION GEARS
BRONZE BEARING
OILER
BRUSH
COMMUTATOR
ARMATURE
GEAR
COMMUTATOR END FRAME
FIELD COIL
DRIVE HOUSING

e. If the over-running clutch type drive is used, we must have a shift fork and linkage to shift the pinion into mesh with the flywheel gear. As we have already said this linkage may be operated mechanically or electrically. If it is electrically operated, a unit called a solenoid is used.

**(1) A solenoid is an electromagnet with a movable core or plunger. It is mounted on top of the starter motor. When the starter switch on the vehicle instrument panel is depressed (in some cases a key operated switch is used), the windings in the solenoid create an electric magnet.**

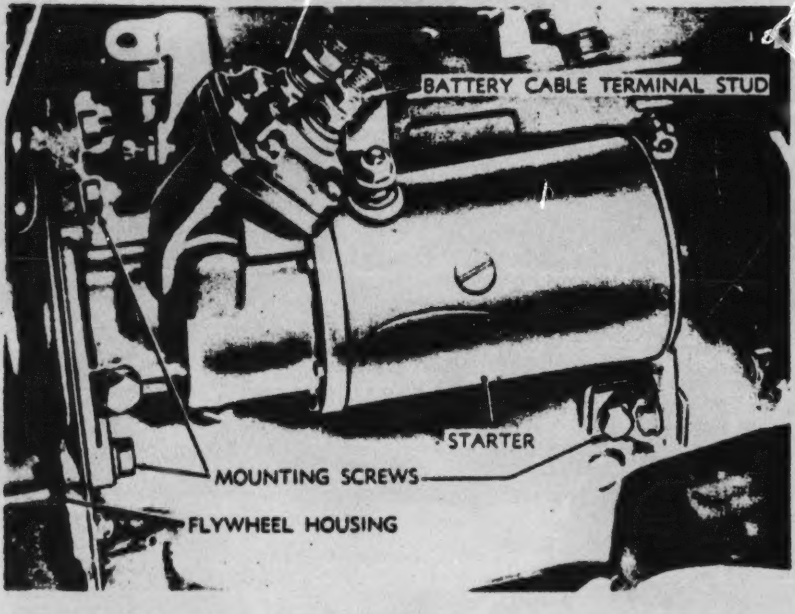

CONTACT PLUNGER
SHIFT PLUNGER
LINKAGE
CONNECTOR
SHIFT LEVER
BRUSH
COMMUTATOR
COMMUTATOR END HEAD
ARMATURE

**(2) Here, in view A, the shift plunger is in its released position, being held there by the contact plunger spring. No current is flowing because the switch for the solenoid winding is open. The starter pinion is not engaged with the flywheel. In view B the operator has closed the switch to the solenoid windings and the solenoid coil is now an electromagnet. The electromagnet pulls the solenoid plunger to the left. This action shifts the pinion into mesh with the flywheel and then closes the starter switch. Now current flows through the starter motor causing the armature to rotate.**


TO STARTER MOTOR
STARTER SWITCH OPEN
INSULATED
SOLENOID COIL
SOLENOID PLUNGER
FLYWHEEL RING GEAR
LINKAGE
A
SWITCH
BAT.
STARTER SHAFT
STARTER DRIVE GEAR
STARTER SWITCH CLOSED
B
BAT.

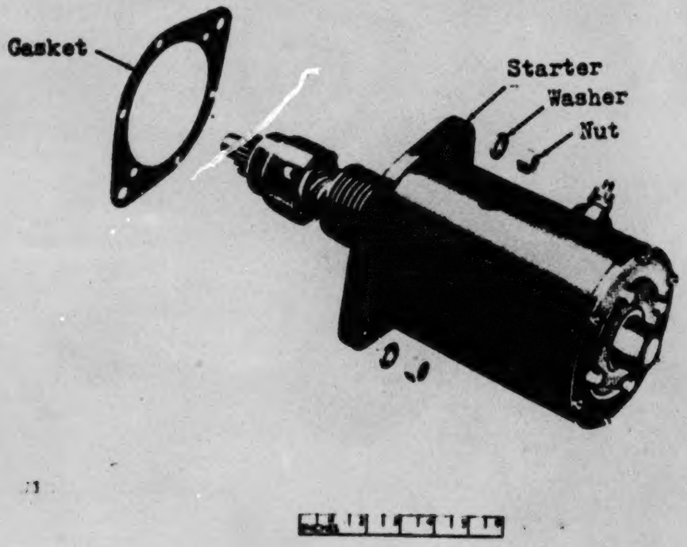
(3) When the switch for the solenoid winding is opened, the spring pushes the plunger back. This breaks the circuit to the starter and pulls the pinion back away from the flywheel.

6. **WATERPROOF STARTERS.** Military tactical vehicles that are expected to ford water deep enough to cover the starter have waterproof starters. Such starters are completely sealed so that no water can enter. Bearings are lubricated on original assembly and need no attention between overhauls.



a. The Autolite starting motor, model MCZ 4005UT, is a typical starter motor in use today on military vehicles. It is a sealed type (waterproof) starter and is used on the 1/4-ton truck M151.

b. The motor operates on 24 volts and is a four-pole, four-brush unit. It is designed for underwater operation but is not completely waterproof unless it is used with a waterproof flywheel housing. A gasket is used to seal the starter to the flywheel housing. The starter is mounted on two flywheel housing studs and held in place by two nuts and two lockwashers.



c. Three bushing-type bearings which require no lubrication are used to support the armature shaft. One bearing is in each end plate, and one in the flywheel housing of the engine. The starter drive is the Bendix Folo-Thru type.

d. The end play of the armature shaft is held within allowable limits by the use of thrust washers of various thicknesses. The pole pieces (soft iron shoes) are attached to the starter frame by countersunk screws. The field winding or coils are positioned around two of the pole pieces, opposite to each other. This gives a four-pole action with only two field windings. The internal resistance is kept low because there are only two windings.

e. When the starter switch is closed, current is passed through the two grounded brushes to the commutator, which is located on the armature shaft. The armature has a number of heavy wires wound around it in such a manner as to produce a magnetic field. After flowing through the armature windings, the current is directed through two insulated brushes to the two field windings and the pole pieces become magnetized. The magnetic fields of the pole pieces oppose the magnetic fields of the armature, causing the armature to rotate. The direction of rotation is counterclockwise as viewed from the drive end of the starter. This direction of rotation is opposite to that of most starters, but this starter is mounted over the transmission instead of being mounted on the engine.

Note. - Complete exercises number 81 through 92 before continuing to section II.

81. The starting motor is a device that changes

a. electrical energy into mechanical energy.
b. mechanical energy into electrical energy.
c. torque into rotational speed.

82. What is required for continuous rotation of the starter armature?

a. High output torque
c. Commutator bars and brushes
c. Alternating field current

83. What is mounted in the laminated iron core of the starter motor armature?

a. Armature windings
b. Commutator bars
c. Armature brush holders

84. What type of winding is used in most starter motors?

a. Shunt
b. Series
c. Compound

85. Magnetic lines of force move parallel to each other and

a. are not affected by other magnetic fields.
b. always oppose each other.
c. will not cross each other.

86. The magnetic field around a wire can be made stronger by increasing the

    a. length of the wire.
    b. resistance in the wire.
    c. current flow in the wire.

87. The rotary motion of the starter motor armature is produced mostly by magnetic

    a. induction.
    b. attraction.
    c. repulsion.

88. The drive gear on the starter armature shaft is usually called a

    a. bevel gear.
    b. planet gear.
    c. pinion gear.

89. Which type of starter drive is usually splined to the armature shaft?

    a. Bendix
    b. Folo-thru
    c. Over-running clutch

90. What is the advantage of the Folo-thru starter drive?

    a. Does not disengage from the flywheel until the engine speed is about 400 RPM
    b. Provides a greater gear reduction than any other type of starter drive
    c. Provides a positive shift of the pinion before the solenoid engages the starter switch

91. The overrunning clutch type of starter drive

    a. eliminates the need for a drive pinion.
    b. positively engages the flywheel without a shift lever.
    c. drives in one direction only.

92. What is an advantage of having a double reduction starter drive mechanism?

    a. Cranks the engine faster
    b. Permits the use of a smaller starter motor
    c. Produces less starting torque

## SECTION II. MAINTENANCE OF CRANKING MOTORS

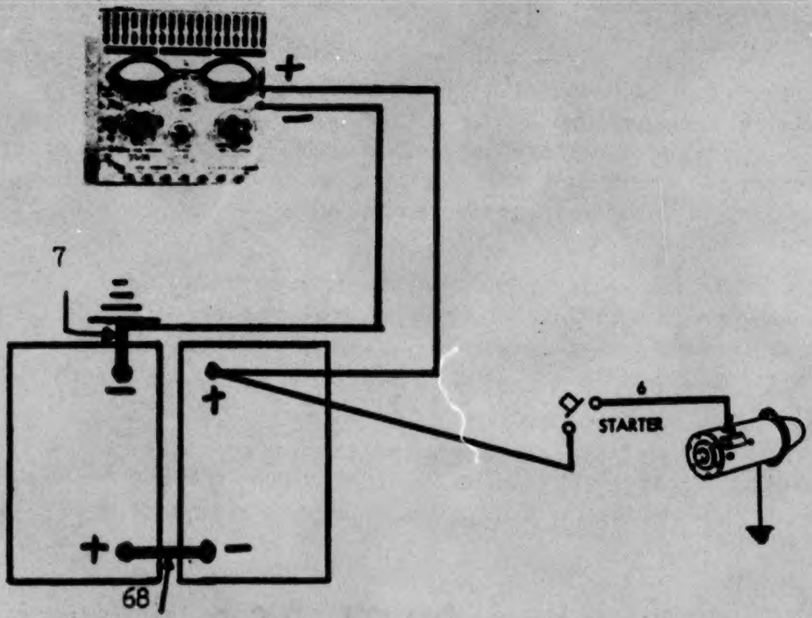
7. **TESTING AND REPAIRING STARTING SYSTEMS.** Many of the electrical troubles that occur in the starter are caused by weak batteries, loose or corroded battery cables, or loose connections in other parts of the circuit. Therefore, all electrical tests on the starter circuit in any vehicle start with the batteries and cables.

a. Before studying the step-by-step procedure for checking the starter circuit with the low-voltage circuit tester (LVCT), it might be a good idea for you to review the lesson on electrical test equipment. Be sure to remove watches and rings before testing the starter circuit.

b. The starter system testing procedures described below are general in nature. The specifications are for the 1/4-ton truck M151. The test procedure for all trucks, except for the specifications, are much alike.

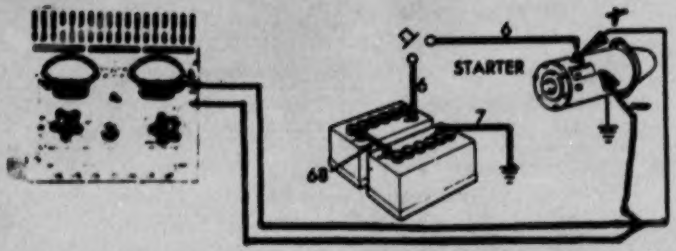
(1) Before making the tests, check the level and specific gravity of the electrolyte in each battery cell. Also clean and tighten all of the battery cable connections to eliminate any possibility of trouble in this area.

(2) With the LVCT voltmeter selector switch in the 50-volt position, connect the positive voltmeter lead to the positive post of the ungrounded battery. Connect the negative voltmeter lead to the cable of the grounded battery post. The voltmeter should read at least 24 volts.

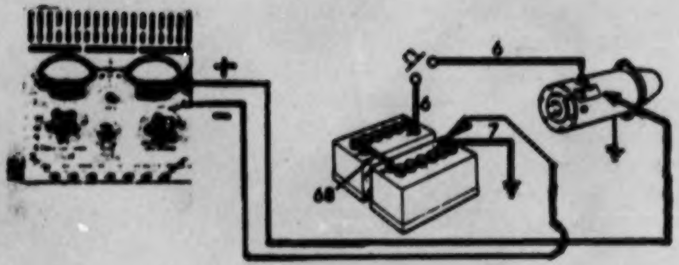


(3) With the voltmeter leads still connected, have your assistant close the starter switch (be sure the ignition switch is off). The voltmeter reading will drop if the starter circuit is good, but it should not drop below 18.5 volts. If it does not drop below 18.5 volts and the starter cranks the engine well, the starting system is good and no further checks are required. If the voltage does drop below 18.5, the trouble could be defective batteries, low internal resistance in the starter motor, or an engine that is too hard to turn. Check each battery separately to be sure they are good. The voltage on each battery should not drop below 9 volts while the starter is cranking. We will discuss testing the starter later in the lesson.

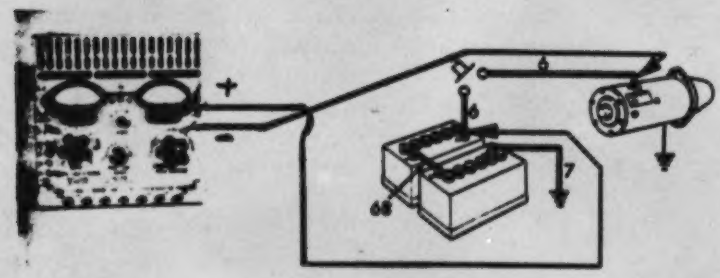
(4) If on the first test the battery voltage did not drop below 18.5, but the engine cranked too slow, other checks will have to be made. We will begin by checking the amount of voltage reaching the starter. First, connect the positive voltmeter lead to the cable terminal on the starter motor. Connect the negative voltmeter lead to the frame or housing of the starter. Be sure the voltmeter selector switch is in the 50-volt position. With the ignition switch off, have your assistant close the starter switch. The voltmeter should read at least 18.5 volts. If the reading is 18.5 volts or more, the starting switch, cable, and batteries are not the cause of slow cranking. Check for a tight engine or a defective starter. If the reading is less than 18.5 and we know the batteries are good, there is probably excessive resistance somewhere in the circuit.



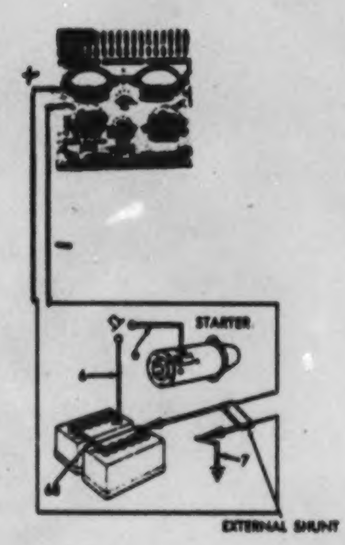
(5) The next test is to find if there is too much resistance in the ground portion of the circuit. To do this, connect the positive voltmeter lead to the starter frame or housing. Connect the negative lead to the the negative post of the ungrounded battery. Set the voltage selector switch in the 50-volt position. With the ignition switch off, have your assistant close the starter switch. If the voltmeter reads less than 1 volt, turn the selector switch to the 1-volt position. If the reading is more than 0.2 (2/10) volt, check for a corroded, loose, or defective ground cable; loose starter; or a missing or loose engine ground strap.



(6) The next check will be for resistance in the cables and starter switch. To make this test, connect the positive lead of the voltmeter to the positive post of the ungrounded battery. Connect the negative lead to the cable terminal. With the ignition switch off and the selector switch in the 50-volt position, have your assistant close the starter switch. The voltmeter reading should drop to almost zero. If it does, move the selector switch to the 1-volt position while the engine is still being cranked. The voltmeter should now be not more than 0.3 (3/10) volt. Move the voltmeter switch back to the 50-volt position while the engine is cranking. If the reading is more than 0.3 volt, there is high resistance between the battery and the starter. This could be caused by frayed cables, loose or corroded terminals, or burned contacts in the starter switch.



(7) Now to check to see how much current the starter draws. Disconnect the battery ground cable from the battery post. Install the external shunt as shown in the figure. If you are working on a small vehicle, and you are sure the current draw will be less than 100 amperes, the regular ammeter leads could be used for this test. However, if you are wrong and the current is over 100 amperes, the meter could be damaged. After the meter is connected, have your assistant close the starter switch. If the ammeter reads more than 40 amperes and the engine is cranking

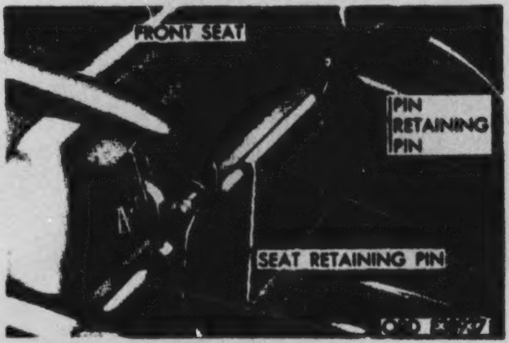


slowly, the starter is defective or the engine too hard to turn. If the reading is less than 25 amperes and the engine is cranking slowly, the starter is defective. Remember, you have made all the other tests before you made this one, so there should be nothing wrong with the rest of the system. You can check to see if the engine is turning too hard by first removing the starter. After the starter is removed, turn the engine flywheel by prying on the ring gear with the transmission in neutral. If the engine will not turn, it is a job for direct support maintenance.

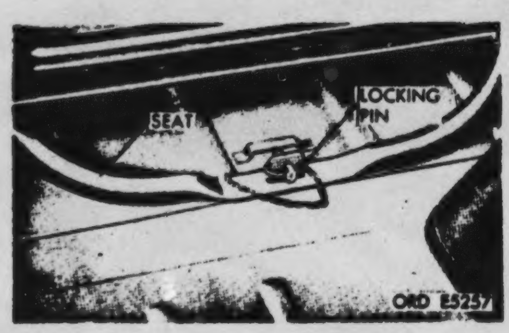
8. STARTING MOTOR REPLACEMENT. The starter motor used on the 1/4-ton truck, M151, is mounted above and on the right side of the transmission. Two studs, lockwashers, and nuts secure the starter to the flywheel housing.

a. To replace the starter, follow the step-by-step procedures outlined below:

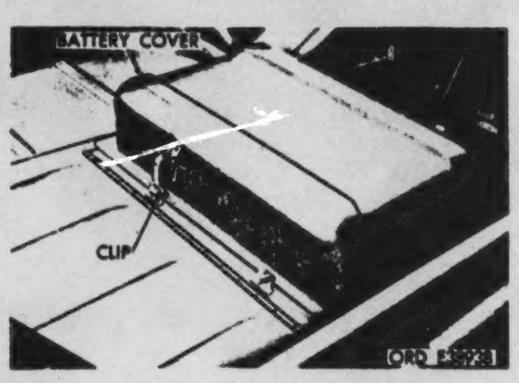
(1) Remove the retaining pins from the front of the right front seat.



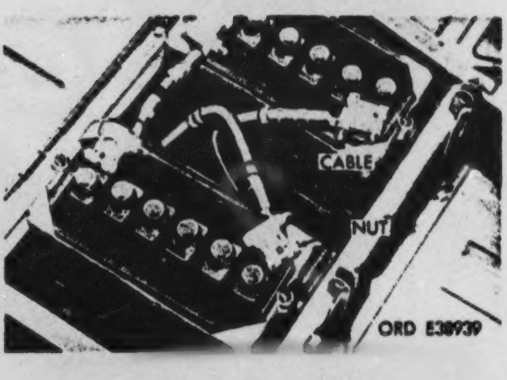
(2) Remove the locking pin from the rear of the right seat and remove the seat from the vehicle.



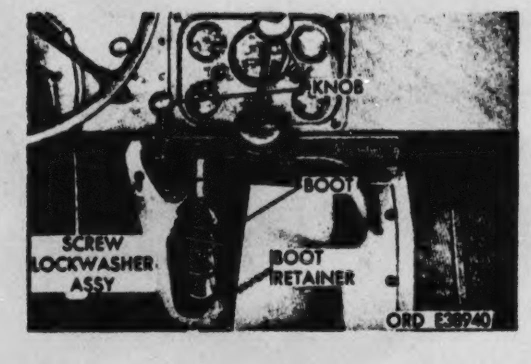
(3) Open the front and rear holddown clips on the battery cover. Remove the cover by lifting straight up.


BATTERY COVER
CLIP
ORD E38938

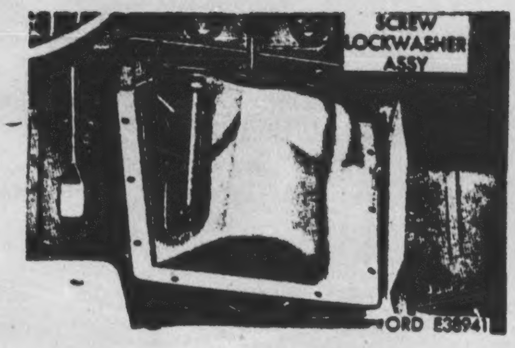
(4) To prevent electrical shock or accidents, loosen the nut on the battery ground cable and lift the cable off of the battery post.


CABLE
NUT
ORD E38939

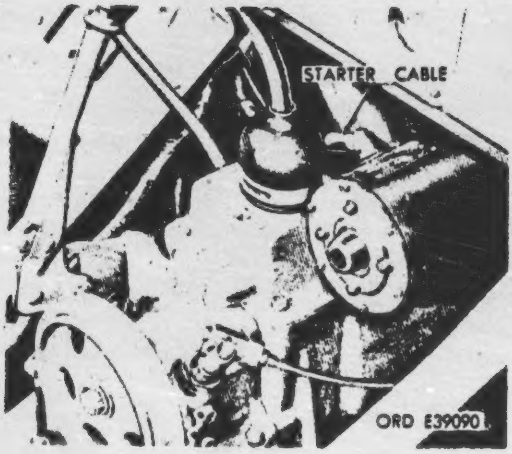
(5) Remove the gearshift knobs, and the 6 screws and lockwashers that secure the boots and boot retainers to the transmission cover plate.


KNOB
BOOT
SCREW
LOCKWASHER
ASSY
BOOT
RETAINER
ORD E38940

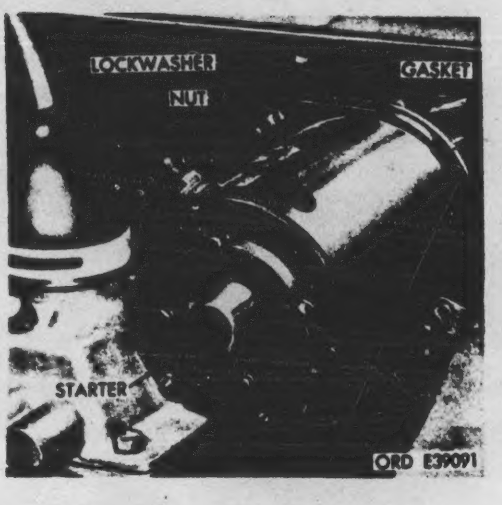
**(6) Remove the 12 screws and lockwashers that secure the transmission cover plate to the floor pan and remove the cover plate.**


SCREW
LOCKWASHER
ASSY
ORD E38941

**(7) Disconnect the starter cable from the starter terminal stud.**


STARTER CABLE
ORD E39090

(8) Remove the two nuts and lockwashers that hold the starter on the flywheel housing studs. Pull the starter motor straight back until it clears the flywheel housing. Remove and discard the starter motor to flywheel housing gasket; install a new gasket with the new starter.



b. To replace the starter, reverse the steps performed to remove it.

Note. - Complete exercises number 93 through 100 before continuing to section III.

93. What test is being made on the starter circuit if the LVCT and the external shunt are being used?

a. Voltage drop
b. Current draw
c. Field resistance

94. When checking the voltage drop through the starter switch, the voltage selection switch of the LVCT should never be moved to the 1-volt position unless the

a. external shunt is used.
b. starter is actually turning.
c. batteries are fully charged.

95. If the starter ground circuit is good a voltmeter connected across it would read approximately

a. 24.0 volts.
b. 18.5 volts.
c. 0.1 volt.

96. Where is the starter motor located on the M151 1/4-ton truck?

    a. Left side of the engine block
    b. Upper right side of the transmission
    c. Lower right side of the flywheel housing

97. Why should the battery ground strap be disconnected before removing any starting system components?

    a. To prevent accidents
    b. To keep the battery from discharging
    c. To test the battery voltage

98. What is likely to be damaged if the starter motor mounting bolts are loose?

    a. The brush holders
    b. The commutator bars
    c. The drive pinion

99. When checking the starting circuit on the M151 1/4-ton truck, what should be done if the battery voltage drops below 18.5 volts?

    a. Replace the starter motor
    b. Check each battery separately
    c. Inspect the starter ground circuit

100. All electrical tests made on the starting system should begin with the

    a. switch and starter motor.
    b. battery and cables.
    c. cables and starter motor.

## SECTION III. CONCLUSION

9. SUMMARY. Starting motors usually give little trouble if given the proper care. Avoid operating the starter when the engine is running. Keep the mounting bolts or nuts tight. Attempting to operate the starter motor with the engine running or with the mounting bolts loose can cause the starter pinion teeth to break off, or, even worse, tear up the teeth on the flywheel. Whenever starter troubles do develop, be sure to follow the step-by-step procedures listed in the vehicle TM to troubleshoot the entire starting circuit. Too often, starter motors have been replaced when all that was wrong was a loose or corroded battery cable.

10. PRACTICE TASK LIST DIRECTIONS. Appendix A contains a list of tasks associated with cranking systems. They are representative of the tasks you will be required to perform as a wheeled vehicle repairman. Perform all of the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

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## APPENDIX A

## PRACTICE TASK LIST

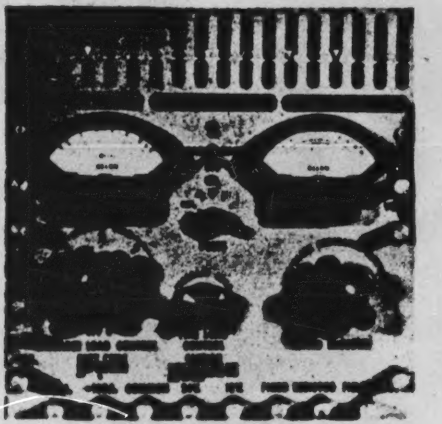
**Practice Objective** - After practicing the following tasks you will be able to:

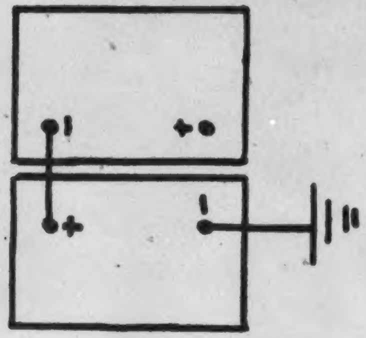
1. Check the battery voltage.
2. Make a starter voltage test.
3. Make a ground loss test.
4. Make a cable and switch voltage loss test.
5. Make a starter draw test.
6. Evaluate the results of the tests.

**Tasks.**

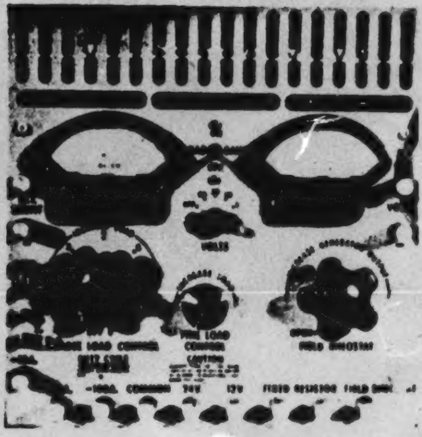
1. In this lesson you will apply some more of the things you learned in the first two lessons of the subcourse. Listed below are a few things you should review and practice. Before you start on the vehicle you should be sure you know how to connect the LVCT, so draw in the test leads on the following schematics.

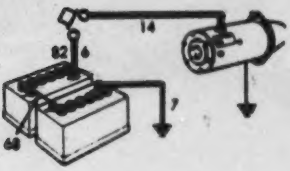
a. Draw in the voltmeter leads as they should be connected to check the battery voltage. After drawing in the leads, refer to the lesson to be sure you are correct.



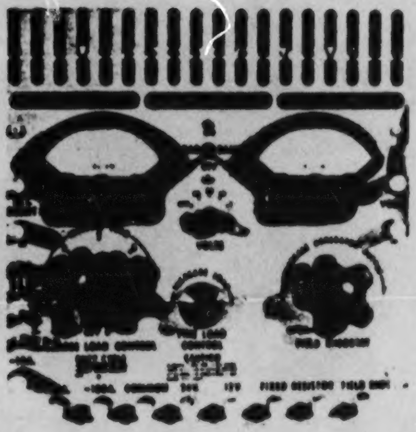


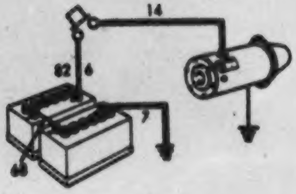
b. Draw in the leads as they should be connected to make a starter switch and cable test of the starter circuit. After you have drawn in the leads, refer to the lesson to see if you are correct.


VOLTS
LOAD CONTROL
FINE LOAD
CONTROL
FIELD RHEOSTAT
-100A.
COMMON
24V
12V
FIXED RESISTOR
FIELD GND

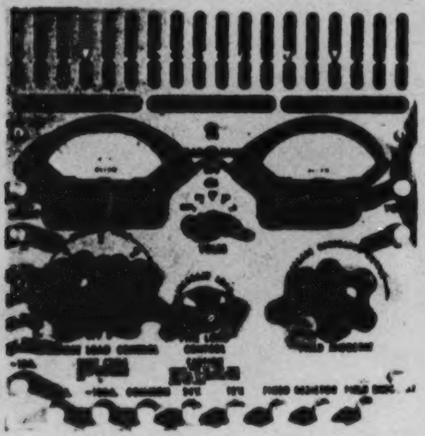


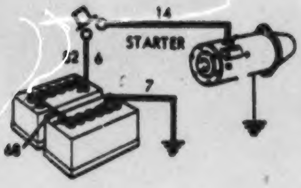
c. Draw in the meter leads as they should be connected to make a starter voltage test. After you have drawn in the leads, refer to the lesson to see if you are correct.





d. Draw in the meter leads as they should be connected to make a starter ground loss test. After you have drawn in the leads, refer to the lesson to see if you are correct.





2. You should now be ready to go to work on the vehicle. Here are a few things you should review and practice.

a. Testing starting systems and components using the LVCT.

(1) Check the battery voltage with the starter operating.

(2) Make a resistance test between the battery and the starter.

(3) Check the starter voltage.

(4) Check the ground circuit resistance.

(5) Check the starter current draw.

b. Remove the starter.

(1) Remove the seats.

(2) Disconnect the battery ground cable.

(3) Remove the transmission cover plate.

(4) Disconnect the starter cable.

(5) Remove the starter.

c. To install the starter use the reverse of the removal procedures.

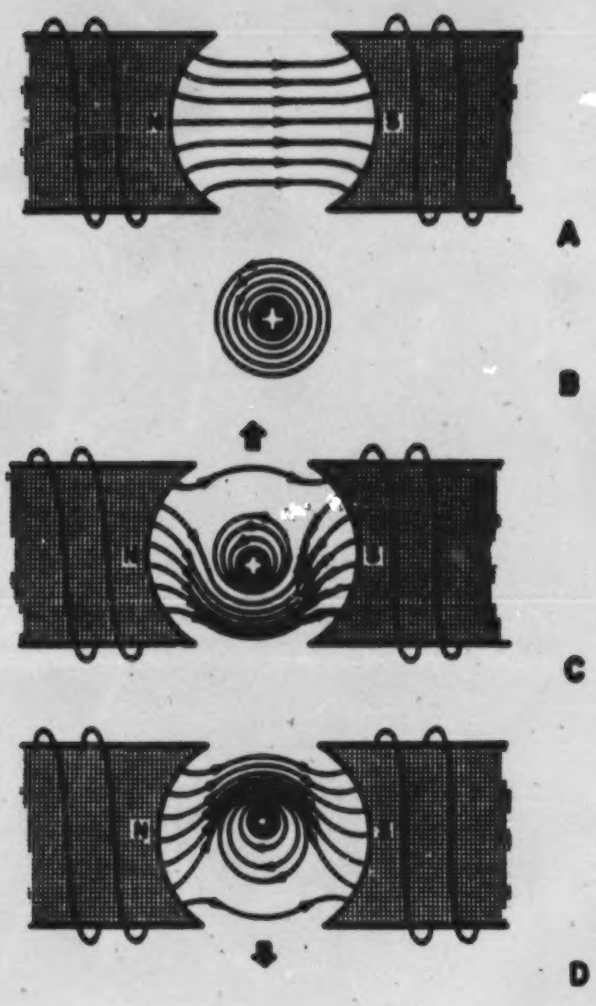
3. By using one of your company vehicles, practice all of the tasks you can. If for some reason you are unable to practice them, you should be able to look at the components on the vehicle and plan ahead on what you will have to do when you are required to make the tests or remove the starter.

## APPENDIX B

## REFERENCES

| | | |
|---|---|---|
| TM 9-8000 | **Principles of Automotive Vehicles** | Jan 56 |

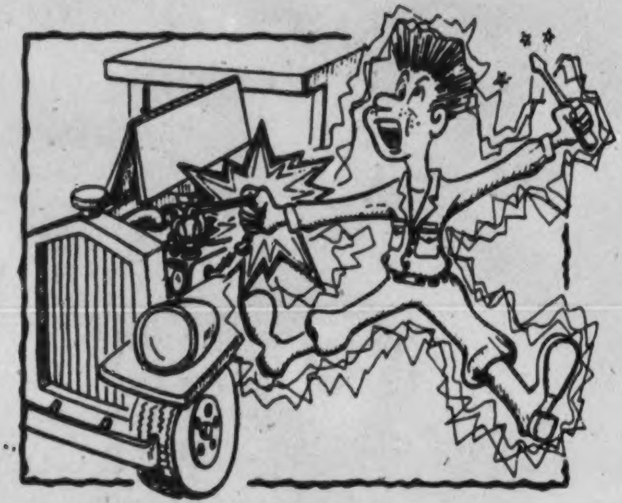
★ U.S. GOVERNMENT PRINTING OFFICE: 1974—620-018/2752 3-1


A
B
C
D

ENLISTED MOS

CORRESPONDENCE/OJT COURSE

# ORDNANCE SUBCOURSE 63B203



## LESSON 6
## INTRODUCTION TO IGNITION SYSTEMS

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

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# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

| | |
|---|---|
| Ordnance Subcourse 63B203. . . | Wheeled Vehicle Electrical Systems |
| Lesson 6 . . . . . . . . . . . | Introduction to Ignition Systems |
| Credit Hours . . . . . . . . . | Two |
| Lesson Objective . . . . . . . | After studying this lesson you will be able to:<br>1. State the purpose of the ignition system.<br>2. Describe the construction of the ignition coil.<br>3. Explain the operation of the ignition coil.<br>4. Describe the construction of the ignition distributor.<br>5. Explain the operation of the distributor.<br>6. Describe the construction of the secondary wiring. |

7. Describe the construction of spark plugs.
8. Explain the operation of spark plugs.
9. Describe the construction of spark advance mechanisms.
10. Explain the operation of spark advance mechanisms.

**Study Assignment** . . . . . . . . . . Study the text and illustrations carefully. The text discusses the construction and function of common ignition system components. It will provide you with a knowledge of how the ignition system components always place the correct amount of spark in the place where it is needed at the exact time it is needed.

**Materials Required** . . . . . . . . . All students: Exercise response list and answer sheet.
Correspondence/OJT option students: See appendix A.

**Suggestions** . . . . . . . . . . . . . None

## STUDY TEXT

## SECTION I. PRINCIPLES OF THE IGNITION COIL

1. INTRODUCTION TO IGNITION SYSTEMS. The simple act of walking into a darkened room, flipping a light switch, and illuminating the previously darkened room is something we take for granted in our everyday lives. We never consider the vast electrical network that is involved in making the light come on.

a. Let's discuss a few factors involved in this seemingly simple act.

(1) First of all, the house must be provided with an electrical source of power. This often originates at a hydroelectric plant that consists of a huge dam to retain a lake of water pressure and huge generators to convert the water pressure to electric power.

(2) This power is then carried by high voltage wires to a stepdown transformer near your home. This reduced voltage is transferred to the fuse box in your home through wires. From the fuse box, the electrical power is carried by wires to the switch you flipped and eventually to the light fixture that provided the illumination for the room.

b. When you step into your car and start it, you again perform what appears as a simple act. You merely turn the ignition switch to the start position until the engine is running and then release the switch. Now let's see what was actually involved in this act.

(1) From previous studies you know that a spark produced at the instant the fuel-air mixture of a cylinder is compressed to the proper pressure will cause a combustion that will drive the piston down.

(2) We also know that when that piston returns to the same position again, another spark will ignite the mixture again.

(3) Just think how fast these sparks must occur at just the right instant in an 8-cylinder engine running at 4,000 RPM.

c. The ignition system is one of the most interesting (and troublesome) systems found on a gasoline engine. It is interesting because it must build up the vehicle's battery voltage from about 24 volts or less to as much as 25,000 or 30,000 volts, and it must do this many times per second. It is troublesome because so many things can and do go wrong in the system.

(1) To give you some idea about how fast the ignition system builds up the battery voltage to as much as 30,000 volts at the spark plug, let's take a 6-cylinder engine turning at 4,000 revolutions per minute (RPM) and see what the ignition system is doing. As you know, in a 4-stroke cycle engine, one-half of the cylinders fire during each revolution of the crankshaft. This means that 3 cylinders of a 6-cylinder engine will fire during each revolution. By multiplying the number of RPM by the number of cylinders firing each revolution, we find that the ignition system in our example must deliver 3 x 4,000 or 12,000 high-voltage surges or sparks per minute. This is equal to 200 sparks per second!

(2) The ignition system not only builds up these high-voltage surges to fire the fuel-air mixture in the engine cylinders, it also times or paces these surges so they will occur in each cylinder just as the piston reaches the end of its compression stroke. So we can say that the ignition system has the job of building up high-voltage surges and timing them to occur in each cylinder at precisely the right instant. How this is done is the story of each ignition system.

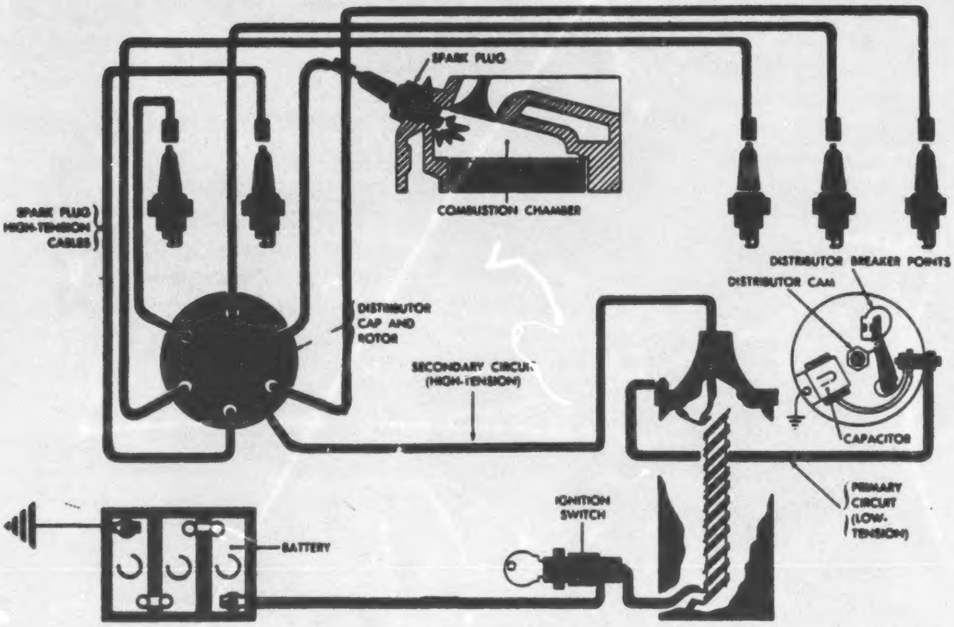
d. The intent of this lesson is to provide you with a knowledge of the construction and operation of the components in an ignition system that provides the spark needed to make an engine run.

2. BATTERY IGNITION SYSTEM COMPONENTS. Although other things are usually added, the basic ignition system consists of the following items:

a. The vehicle's battery or batteries and the generator to supply the required current. While the engine is being cranked, the batteries supply the low-voltage current to the ignition system. When the engine is running and the generator is charging, it takes over the job of supplying current to the system.

b. The ignition switch opens and closes the circuit between the batteries and the other components in the ignition system. We usually stop the engine by turning off (opening) the ignition switch.

c. The ignition coil is the device that converts the low voltage from the batteries to the high voltage needed to ignite the fuel-air mixture in the engine cylinders.


SPARK PLUG
COMBUSTION CHAMBER
SPARK PLUG HIGH-TENSION CABLES
DISTRIBUTOR BREAKER POINTS
DISTRIBUTOR CAM
DISTRIBUTOR CAP AND ROTOR
SECONDARY CIRCUIT (HIGH-TENSION)
CAPACITOR
PRIMARY CIRCUIT (LOW-TENSION)
IGNITION SWITCH
BATTERY

*Schematic wiring circuits of an ignition system.*

d. The ignition distributor alternately opens and closes the low-voltage circuit through the coil. It also receives the high-voltage surges from the coil and distributes them to the proper cylinders to burn the fuel-air mixture. The low-voltage circuit is better known as the primary circuit, while the high-voltage circuit is better known as the secondary circuit. In the remainder of this lesson we will refer to them as the primary and secondary circuits.

e. The high-tension (voltage) wires carry the high-voltage surges to the spark plugs.

f. The spark plugs provide an airgap in each cylinder for the high-voltage surges to arc across. Here is the reason we need such high voltage in the secondary circuit. It takes a lot of voltage to force the current to jump across the airgap between the electrodes of a spark plug. The current, arcing across the airgap, is what actually ignites the fuel-air mixture.

g. The primary circuit consists of the components between the battery and the breaker points, including the breaker points. The secondary circuit consists of the secondary winding in the coil, the distributor cap and rotor, the distributor, spark plug wires, and spark plugs.

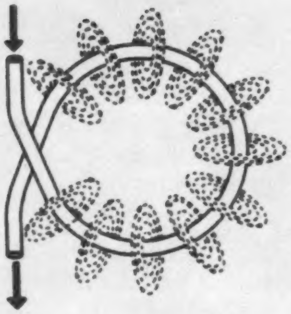
3. CONSTRUCTION AND OPERATION OF THE IGNITION COIL. The ignition coil is really a step-up transformer. You have probably noticed transformers on the light wire poles near your home. These are usually step-down transformers which change the high voltage in the transmission wires on the poles to the 110-volt current you use in your home. Our ignition coil does just the reverse of the step-down transformer. It changes the low voltage supplied by the battery or the generator to the high voltage needed at the spark plugs.

a. To understand how a coil works, let's review the relationship between electricity and magnetism. We know that when current flows through a conductor, a magnetic field is created around the conductor. The strength of the magnetic field depends on how much current is flowing through the wire and how many loops or coils of wire there are.

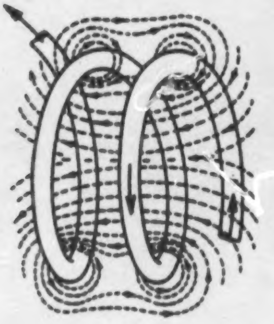
(1) The magnetic fields differ in their flux paths when there is a single, double, or multiple coil of wire carrying the current. We can make a magnetic field stronger simply by increasing the number of coils or turns of the wire.

(2) The strength of the magnetic field around the coil can also be increased in two other ways. First, it can be strengthened by increasing the amount of current flowing in the coil; second, it can be strengthened by inserting a soft iron core inside the coil of wire. Placing a soft iron core in the center of the coil will provide an easier path for the magnetic lines of force, or, to put it another way, the core will increase the number of lines of force because it will reduce the resistance in the magnetic field. It is much easier for the lines of force to travel through an iron core than it is to travel through the air.

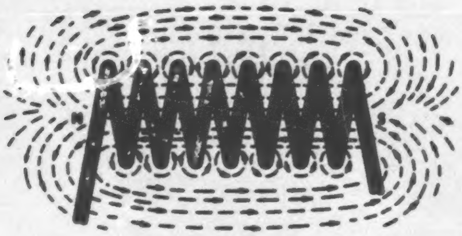
(3) Now recall that a magnetic field can induce current into a conductor provided the conductor is moved through the field or if the field is moved across the conductor. In the case of our coil, however, as long as direct current flows through the conductor, no current will be induced because there is no relative movement between the coil and the magnetic field.



Magnetic field in loop of wire carrying current.



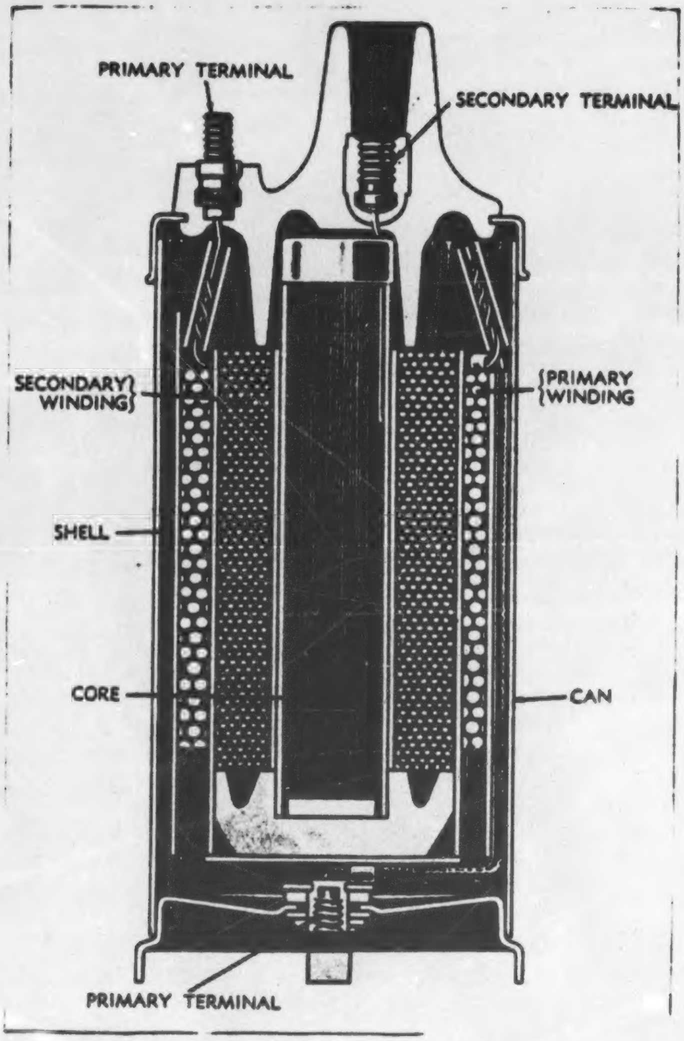
Magnetic field in two adjoining loops of wire carrying current.



Magnetic field produced by current flowing in an electromagnet.

b. Now let's study the construction of the coil. Here we show a coil that has been cut away to show the primary winding, secondary winding, soft iron core, and the terminals for the windings. The primary winding is the large wire and the secondary winding is the small wire. The actual diameter of the wire used in the secondary winding of the coil is about the same as one of the hairs on your head, or less than 0.005 of an inch. With such a small wire we can have thousands of turns of wire in the secondary winding in a small space.

(1) One end of the secondary winding is connected to the high-tension lead of the secondary terminal on top of the coil. The other end is usually connected to one end of the primary winding, although it may be grounded to the metal can that surrounds the coils and the core.


PRIMARY TERMINAL
SECONDARY TERMINAL
SECONDARY WINDING
PRIMARY WINDING
SHELL
CORE
CAN
PRIMARY TERMINAL

*Sectional drawing of ignition coil.*

(2) There are 2 terminals in the coil assembly for the primary winding. One terminal is connected to the wire from the ignition switch which connects and disconnects the coil from the battery. The other terminal is connected to the movable breaker point in the distributor.

c. When the ignition switch and breaker points are closed, current flows through the primary winding of the coil. The current flowing through the few hundred turns of the primary winding builds up a strong magnetic field. This field surrounds the primary and the secondary windings and makes the iron core a strong electromagnet.

d. Remember, that in order to induce a voltage into a conductor we must have a magnetic field and relative motion between the conductor and the magnetic field. We do get relative motion between the field and the conductors when current starts to flow in the primary windings, but this buildup is too slow to induce a voltage in the secondary winding that is strong enough to jump the airgaps in the distributor cap and spark plugs. When the magnetic field reaches its maximum strength, there is no relative motion between it and the windings, so no current will be induced in the windings.

e. Suppose we suddenly shut off the current flowing through the primary winding by opening the breaker points. The magnetic field would collapse and disappear. As it collapses, its lines of force would cut across the primary and secondary windings at tremendous speed. The lines of force collapsing across the windings would induce a voltage into each turn of the coil's windings. The voltage induced into the primary winding is called self-induced voltage because the magnetic field was created by the primary winding in the first place. The voltage induced in the secondary winding is the result of what is called mutual induction. The secondary winding did nothing to create the magnetic field, but a voltage is induced into it because it is "mutually" located with respect to the primary winding.

f. How much voltage will be induced into the primary and secondary windings by the collapsing magnetic field? Well, that will depend on the speed with which the field collapses (speed of the motion) and the number of turns of wire in each coil. The more turns of wire in the windings, the greater the induced voltage will be. In the primary winding of most automotive coils there are a few hundred turns of wire, and the voltage induced will be about 200 or 250 volts. Because the primary circuit is now open (that is why the magnetic field collapsed), this voltage isn't going anywhere except into the capacitor which we will study later. While the magnetic field is collapsing across the few hundred turns of primary winding, it is also moving across the thousands of turns of secondary winding. The voltage induced into each turn of each winding is about the same. Since the secondary winding has many more turns, the total voltage induced into it will be in the thousands of volts. This voltage is high enough to force current to flow out the coil, through the secondary terminal, and through the conductors to the spark plug in the cylinder. There the current is forced, by the high voltage, to jump the airgap and ignite the fuel mixture. This current then returns to its source, in this case the secondary winding of the coil.

**Note.** - Complete exercises number 101 through 103 before continuing to section II.

101. How many revolutions per minute (RPM) is a 4-cylinder, 4-stroke cycle engine turning if the ignition system is delivering 1,600 sparks per minute?

a. 3,200
b. 1,600
c. 800

102. The secondary winding in an ignition coil is usually grounded to the

a. coil case.
b. primary winding.
c. iron core.

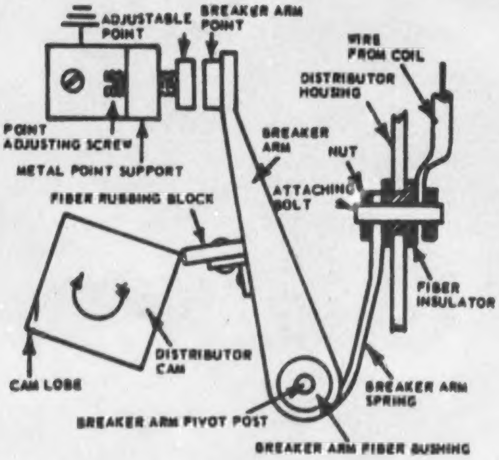
103. The spark producing high voltage is induced into the secondary winding of the coil during the

a. buildup of the magnetic field.
b. collapse of the magnetic field.
c. time the points are closed.

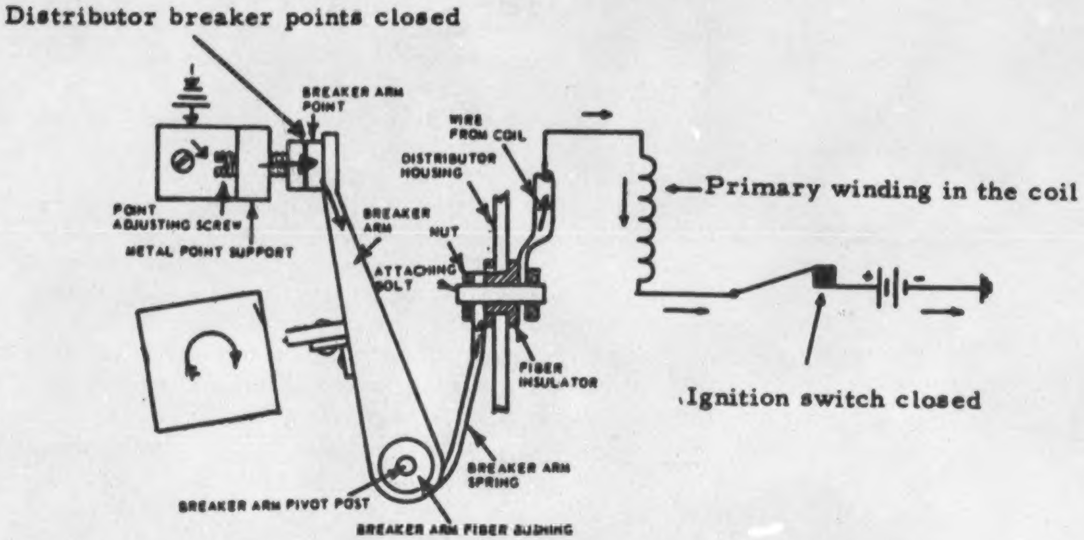
## SECTION II. PRINCIPLES OF THE IGNITION DISTRIBUTOR

**4. CONSTRUCTION AND OPERATION OF THE IGNITION DISTRIBUTOR.** We stated earlier in this lesson that the ignition distributor had two separate and distinct jobs to do. One job involved the primary circuit while the other job was concerned with the secondary circuit. Let's discuss the primary circuit first. The parts we will discuss are the distributor breaker points, distributor cam, and the capacitor (condenser).

a. The points consist of two contacts one of which is stationary and grounded and one which is insulated and movable. When mounted in the distributor, the spring end of the movable breaker arm assembly is connected to the primary lead from the coil. The breaker arm is mounted on a pivot post. The arm is insulated from the post by a fiber bushing. The entire arm can swing back and forth on the pivot post. A fiber rubbing block is kept in contact with the distributor cam on the distributor shaft during the time the breaker points are open. The distributor shaft is driven in time with and at one-half the speed of the engine crankshaft. On most distributors the cam will have one cam lobe for each cylinder of the engine. The grounded point is attached to a support which, in turn, is mounted on a plate inside the distributor. While this point is often called the stationary point, it can be moved to adjust the point opening. This is done by moving the adjustable point either nearer to or farther from the insulated point. On some distributors the adjustable point is moved in the support to make the adjustment. In other applications the support is moved. Let's see just what happens with these parts when the distributor is in operation.

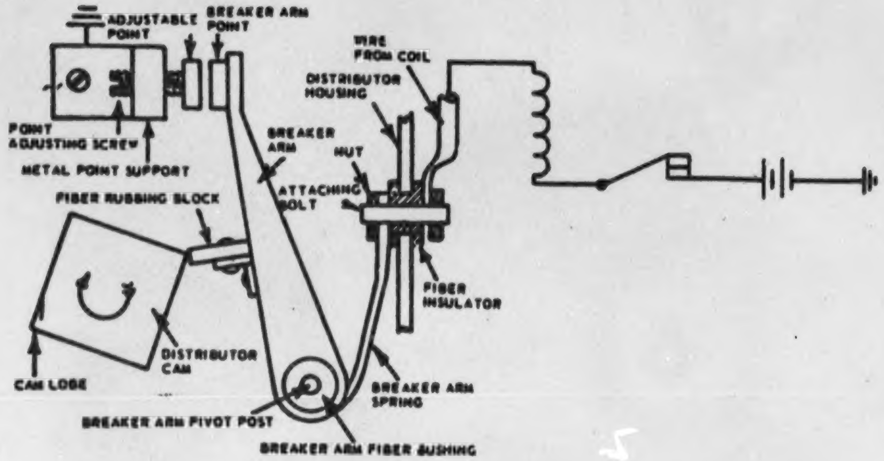

ADJUSTABLE POINT
BREAKER ARM POINT
WIRE FROM COIL
DISTRIBUTOR HOUSING
POINT ADJUSTING SCREW
BREAKER ARM
NUT
METAL POINT SUPPORT
ATTACHING BOLT
FIBER RUBBING BLOCK
FIBER INSULATOR
DISTRIBUTOR CAM
CAM LOBE
BREAKER ARM SPRING
BREAKER ARM PIVOT POST
BREAKER ARM FIBER BUSHING

b. While the low side of the cam is toward the rubbing block, the breaker arm spring holds the contact points closed. At this time current can flow from the batteries to ground, then from the grounded contact to the insulated contact. From here it will flow out through the primary windings of the ignition coil. This causes a strong magnetic field to build up around the coil. From the primary of the coil, current returns through the closed ignition switch to the battery.


Distributor breaker points closed
BREAKER ARM POINT
WIRE FROM COIL
DISTRIBUTOR HOUSING
Primary winding in the coil
POINT ADJUSTING SCREW
METAL POINT SUPPORT
BREAKER ARM
NUT
ATTACHING BOLT
FIBER INSULATOR
Ignition switch closed
BREAKER ARM SPRING
BREAKER ARM PIVOT POST
BREAKER ARM FIBER BUSHING

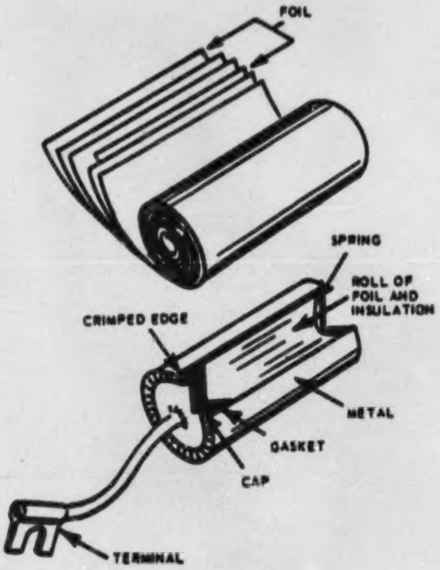
(1) Current will continue to flow as long as the circuit is closed. When the cam turns enough, a lobe on the cam will contact the rubbing block, then push the contact points open. This opens the primary circuit, and the magnetic field rapidly collapses around the windings in the coil. As the cam continues to turn, the lobe will move from under the rubbing block. At this time the spring will again close the points. As each lobe in turn strikes the rubbing block, the above action takes place.

(2) So far we have seen how the magnetic field builds up in the ignition coil while the points are closed. Also, when the cam lobe opens the points, the circuit is broken and the coil's magnetic field collapses. This induces a very high voltage in the secondary winding of the coil. This high voltage forces current to jump the airgap at the spark plug electrodes and ignite the fuel-air mixture in the cylinder.

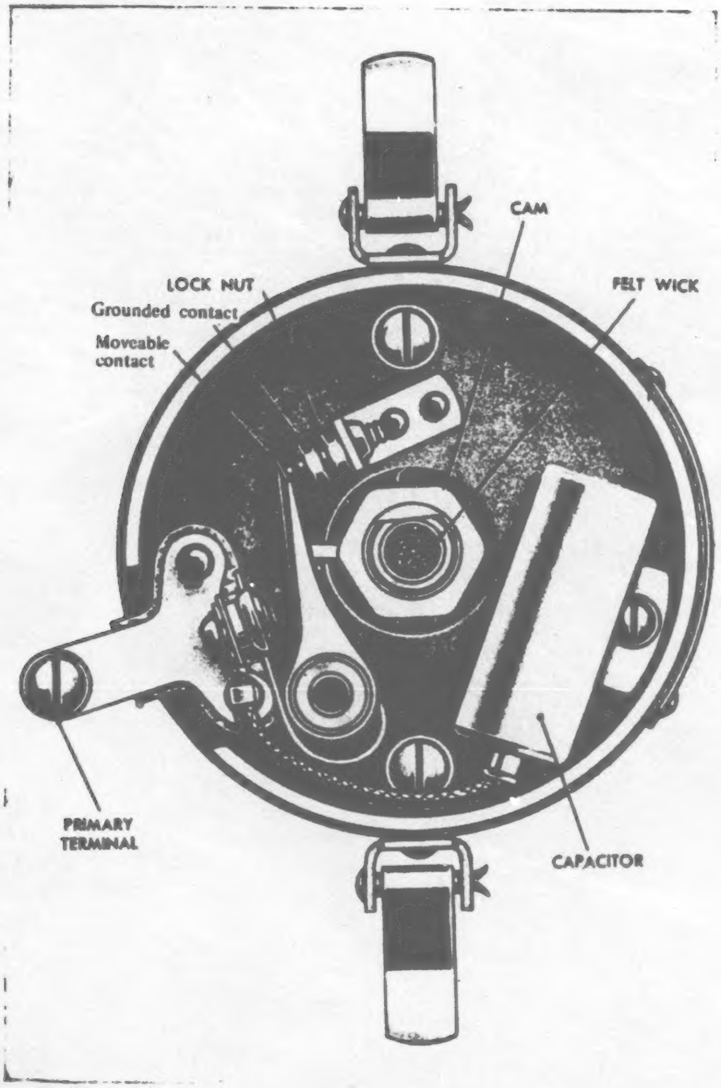

ADJUSTABLE POINT
BREAKER ARM POINT
WIRE FROM COIL
DISTRIBUTOR HOUSING
POINT ADJUSTING SCREW
METAL POINT SUPPORT
BREAKER ARM
NUT
ATTACHING BOLT
FIBER RUBBING BLOCK
FIBER INSULATOR
DISTRIBUTOR CAM
CAM LOBE
BREAKER ARM SPRING
BREAKER ARM PIVOT POST
BREAKER ARM FIBER BUSHING

(3) In practice, however, creating the high voltage in the coil is not quite so simple. Actually, electricity, like anything else in motion, tries to remain in motion. It resists any effort to change or stop its flow. Also, the magnetic field in the coil is collapsing around the primary windings as well as the secondary. This builds up voltage in the primary windings. The end result of all this is that current will arc across the points. This arcing will cause the points to burn and be destroyed in a very short time. It also causes the magnetic field in the coil to collapse more slowly. Remember, we get a high voltage induced into the coil's secondary windings only if the magnetic field collapses real fast.

(4) To reduce arcing across the points and to speed the collapse of the magnetic field in the coil, a capacitor is used. For years automotive mechanics have referred to the capacitor as a condenser. As you will see, however, capacitor is a more accurate term. The capacitor consists of two sheets of metal foil, called plates, which are separated by insulating paper and then rolled together. One roll of foil is connected to a wire lead, while the other roll is connected to the metal can or case.



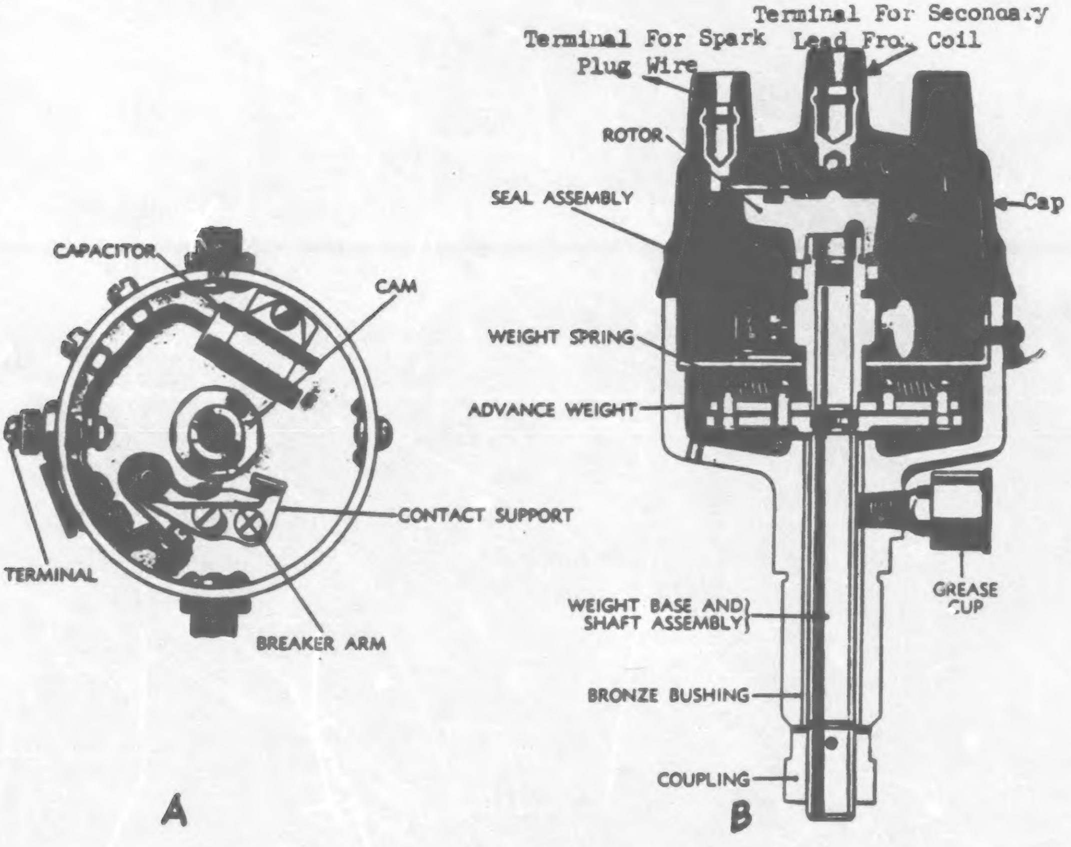
(5) The lead of the capacitor is connected to the same terminal as the insulated breaker point. The capacitor case is grounded to the distributor plate by a screw. This is a parallel connection, because , current can go through the points or into the capacitor. When the points are closed the current goes through the points because the foil strips in the capacitor are insulated from each other.


CAM
LOCK NUT
FELT WICK
Grounded contact
Moveable contact
PRIMARY TERMINAL
CAPACITOR

(6) As the cam lobe moves the rubbing block and barely separates the points, the voltage in the primary windings will start to rise and attempt to force current across the points. The capacitor now offers an easier path for the current to take, so current will flow into the capacitor and charge it electrically. By the time the current charges the capacitor the points will have opened wide enough so that the current can no longer jump the gap between the contacts. In this manner, the capacitor protects the breaker points.

c. The secondary circuit in the distributor consists of the rotor and distributor cap and is discussed in the following paragraphs.

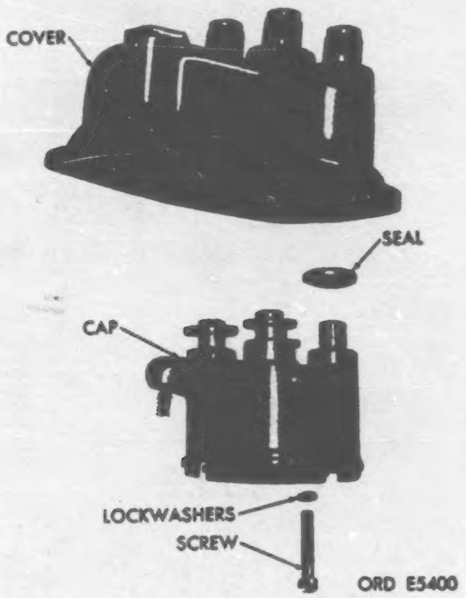
(1) The distributor cap is made of bakelite or some other hard insulating material. It contains terminals (usually called towers) for each spark plug wire and for the high-tension wire from the secondary terminal in the ignition coil. A contact for each terminal extends through the cap.


Terminal For Secondary Lead From Coil
Terminal For Spark Plug Wire
ROTOR
SEAL ASSEMBLY
Cap
CAPACITOR
CAM
WEIGHT SPRING
ADVANCE WEIGHT
CONTACT SUPPORT
TERMINAL
BREAKER ARM
WEIGHT BASE AND SHAFT ASSEMBLY
GREASE CUP
BRONZE BUSHING
COUPLING
A
B

*Distributor—top view (without cap) and side sectional view.*

(2) The rotor, which is also made of bakelite, is mounted on and rotated by the distributor shaft. It has a flat spring-type conductor that stays in contact with the coil's secondary terminal in the center of the distributor cap. The spring, in turn, is connected to a blade-type contact on the top of the rotor. As the rotor is rotated by the distributor shaft, this contact passes very close to each spark plug terminal in turn.

(3) The engines used in the Army's tactical wheeled vehicles are designed to operate under water. This means that the ignition system must be waterproof. The distributor is made waterproof by a cover mounted over the distributor cap. The ignition coil is mounted inside the distributor housing and is also protected from water by the cover. The cover contains threaded waterproof terminals for the spark plug cables.



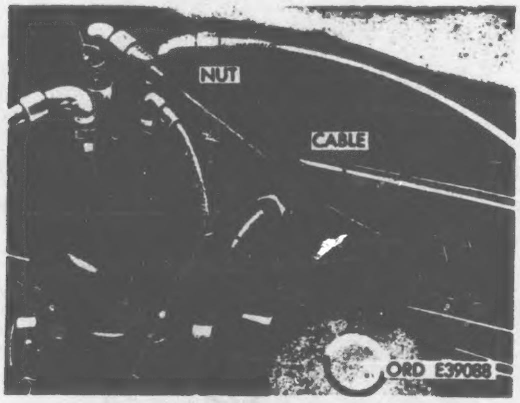
5. CONSTRUCTION AND OPERATION OF THE SECONDARY WIRING AND SPARK PLUGS. The secondary wiring is part of the high-voltage circuit outside the distributor.

a. On civilian-type vehicles, this wiring consists of a cable or wire from the ignition coil to the center tower in the distributor cap. Other wires will lead from the outside towers to the spark plugs.

(1) The wires themselves are very small, only a few strands of very fine wire. The insulation is very thick in order to prevent the high-voltage current, traveling through the wire, from arcing to ground before it gets to the spark plug.

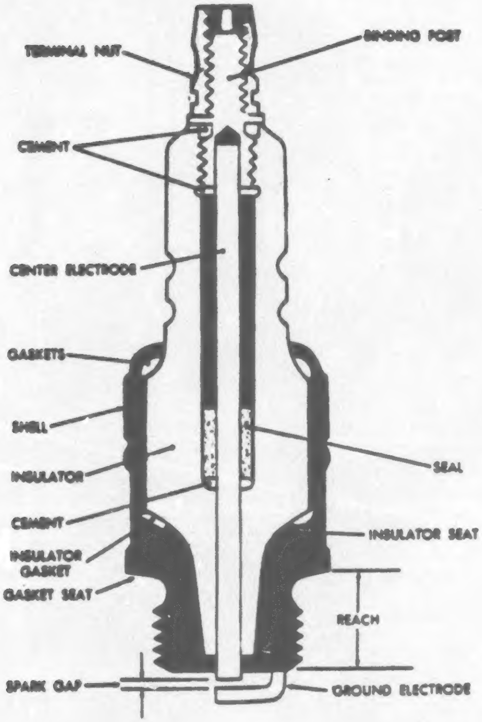
(2) Other type cables may use a carbon saturated string, instead of a wire, as a conductor. The main reason for this is to cut down on noise that can be picked up by radio.

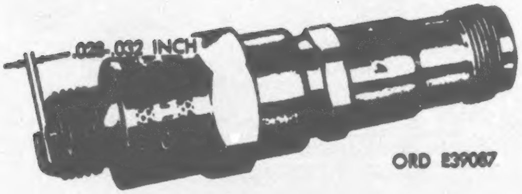
(3) On waterproof ignition systems, the high-tension cable will be inside of a waterproof tube. A woven metal shielding around this tube will reduce radio interference (static) when the engine is running. A nut and a waterproof seal are used on each end of the cable to make a waterproof connection at the distributor and the spark plug.



b. The spark plug (the remaining part of the secondary circuit) consists of a metal shell, a procelain insulator with an electrode extending through it, and a ground electrode which is attached to the metal shell. The shell has external threads to allow it to be screwed into a threaded hole leading to the combustion chamber. The insulated and the grounded electrodes are separated by an airgap (also called a spark gap) of 0.025 to 0.040 of an inch. In operation, the high-voltage current produced in the secondary winding of the coil will arc across the spark plug airgap to ignite the fuel.

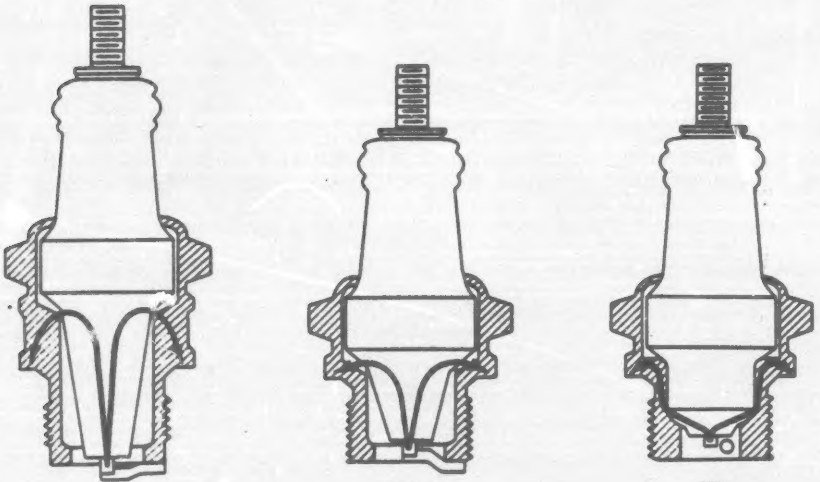
(1) Spark plugs used in waterproof systems are much like the ones we have just discussed, except this type plug will be completely surrounded by a metal shell to which the nut on the spark plug cable is threaded. This shell is for both shielding and waterproofing the spark plug.


TERMINAL NUT
BINDING POST
CEMENT
CENTER ELECTRODE
GASKETS
SHELL
INSULATOR
CEMENT
INSULATOR GASKET
GASKET SEAT
SEAL
INSULATOR SEAT
REACH
SPARK GAP
GROUND ELECTRODE


.028-.032 INCH
ORD E39087

(2) **Spark plugs are usually classified in two ways: first, as to the diameter of the threaded hole into which they are screwed (10mm, 14mm, 18mm, etc) and second, according to the heat range of the plug.**

(3) The heat range, or operating temperature of a spark plug, is determined by the length of the insulator nose. The spark plug, when in operation, is exposed to the heat of the burning fuel. In order for the plug to cool, the heat will have to pass up through the insulator nose to the shell of the plug and from there to the cylinder head or engine block. The farther the heat has to go to get to the shell of the plug, the hotter the spark plug will operate. This means a spark plug with a short insulator nose will operate cooler than one with a long insulator nose.



*Heat paths in different plugs.*

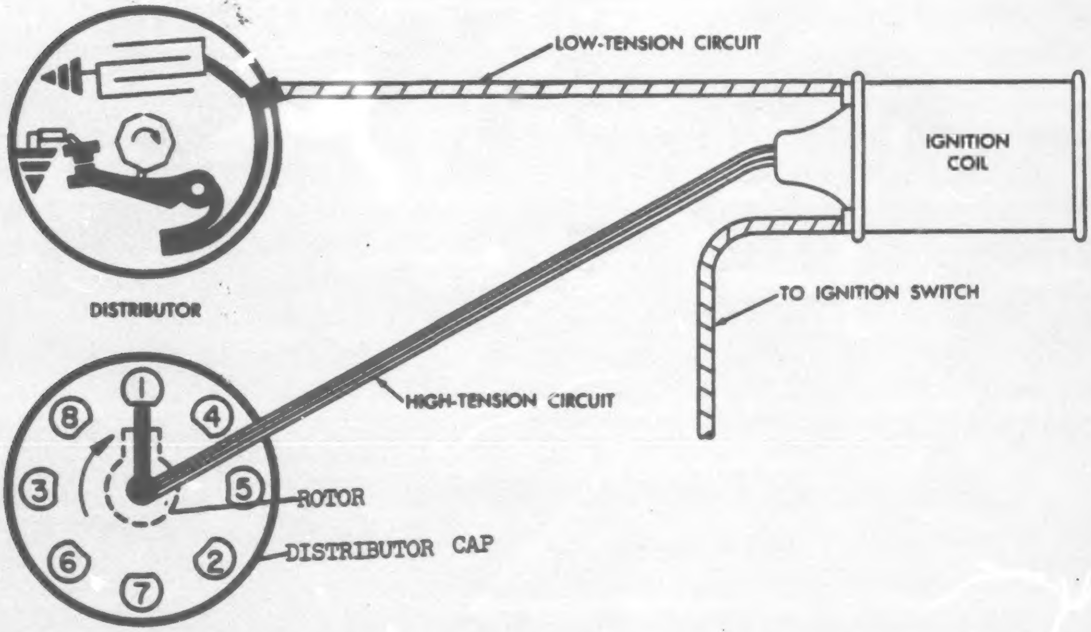
(4) The correct spark plug for any given engine can vary considerably. A hot plug will work better in an engine that is burning oil or in one that is operated at low speeds or short distances. A colder plug may be needed in the same engine if it is operated at high speed over long distances or under heavy loads.

(5) You can determine whether or not a spark plug of the correct heat range is being used by examining the insulator nose. If the deposits on the nose are a light grey or brown ash, the heat range is correct. If the nose is covered with a black, gummy carbon, the plug is too cold. A blistered nose, or one with the porcelain chipped off, is probably too hot.

c. Before we go any farther, let's see just what happens when all the things we have discussed so far in this lesson are in operation. Let's start with the number 1 piston going up on the compression stroke. At this time the air-fuel mixture in the cylinder is being squeezed into a small area of the combustion chamber. With the ignition switch and the breaker points closed, a magnetic field is building up in the ignition coil.

(1) When the piston reaches near top dead center on the compression stroke (the exact point will depend on engine design and engine speed) ignition of the fuel should take place. This is made possible by the fact that the distributor is turning in time with the engine.

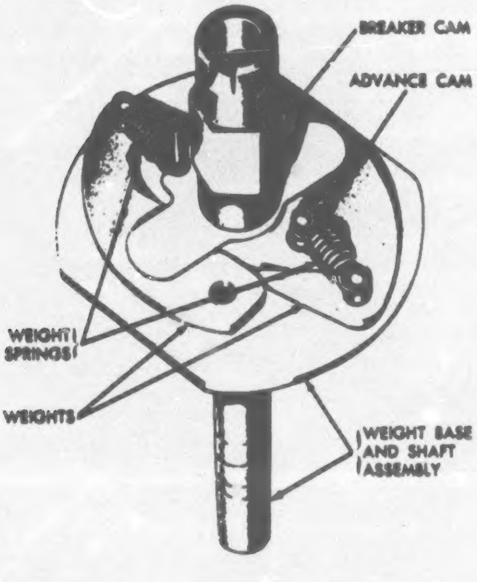
(2) As the cam in the distributor turns, one of the cam lobes will contact the rubbing block on the insulated point. If the distributor is in proper time with the engine, the contacts will open at the time the fuel should be ignited. When the contacts in the distributor open, the primary circuit is broken and the magnetic field collapses. The collapse of the field induces high voltage in the secondary windings of the coil. This high-voltage current then passes to the center of the distributor cap and to the rotor. The rotor at this time is in line with the number 1 tower on the distributor cap. Current passes from the tower to the spark plug wire and on to the spark plug. As the engine and distributor continue to turn, the remaining spark plugs receive the high voltage from the coil at the proper time and in the proper sequence.



6. **CONSTRUCTION AND OPERATION OF SPARK ADVANCE MECHANISMS.** Spark advance mechanisms are necessary in order to have the spark occur in the combustion chamber at exactly the right instant for all engine speeds. At idle, the spark is usually timed to occur at about 2° to 10° before TDC. At high speed, the spark may occur as much as 40° or more before the piston reaches TDC on its compression stroke. It is necessary to start the fuel-air mixture burning sooner at high speeds because the piston is traveling much faster. In fact, without a spark advance, the piston would be well past TDC and moving downward before the burning fuel-air mixture could create enough pressure for an effective power stroke.

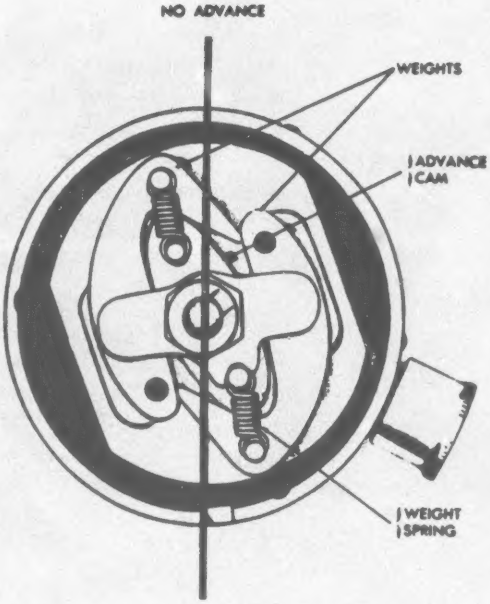
a. There are two types of advance mechanisms in common use that will cause the distributor to deliver a spark sooner in the cycle at high speeds. These mechanisms are the centrifugal advance and the vacuum advance.

(1) The centrifugal advance mechanism is used on all of the Army's tactical wheeled vehicles. This mechanism consists of a pair of weights mounted on pins on the weight base which is fixed to the distributor drive shaft. The weights are connected by springs to the advance cams. These cams are fixed to the bottom of the breaker camshaft.

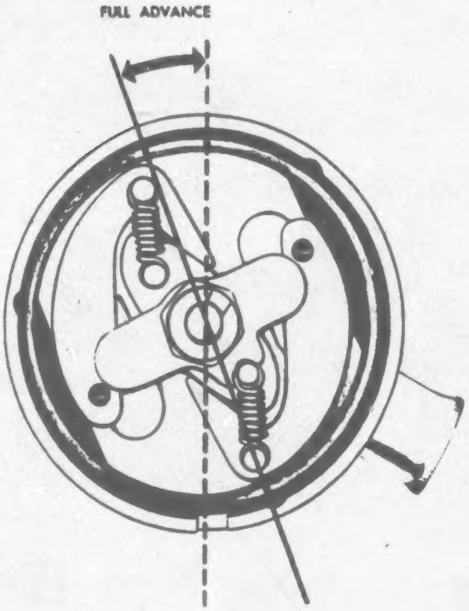


*Centrifugal advance mechanism.*

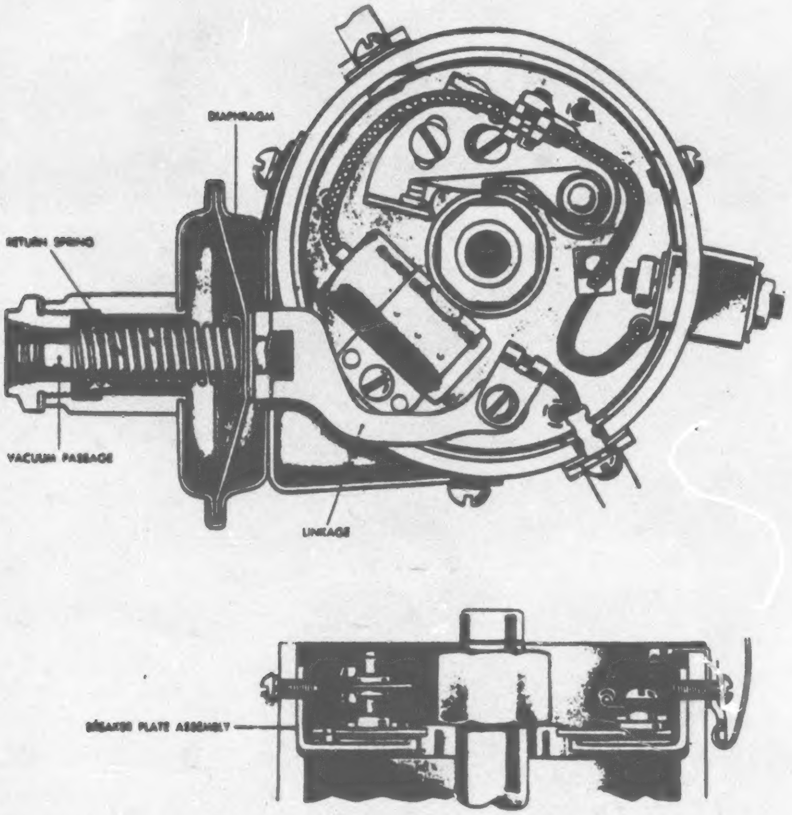
(2) Now let's see how this advance mechanism works. With the engine running at an idle speed, the springs hold the weights in their retarded (no advance) position. As the engine is speeded up, the weights try to fly outward but to do this they must first overcome spring tension, which they will do once the engine is running fast enough. As the engine speeds up the weights move out gradually, not all at one time. This gives a smooth even advance.



(3) Let's suppose that the engine has speeded up to its governed speed. At this time the weights have moved outward as far as they can. As the weights moved, the hooks on the free end of the weights rotated the distributor cam in the direction of cam rotation. Now, each of the distributor cams will strike the rubbing block on the movable point sooner in the cycle, causing the points to open sooner. This action causes the spark to occur in the combustion chamber earlier during the compression stroke of the engine, or advance the time the spark occurs.



b. Vacuum advance mechanisms are not used on tactical wheeled vehicles, but they are commonly used on civilian-type vehicles and on Army staff cars. This type of advance uses a vacuum chamber which is connected to the intake manifold, and a vacuum diaphragm which is linked to the distributor plate. There is a diaphragm spring on the vacuum side of the diaphragm.


DIAPHRAGM
RETURN SPRING
VACUUM PASSAGE
LINKAGE
BREAKER PLATE ASSEMBLY

*Vacuum advance mechanism.*

(1) When the engine is not running, air pressure on both sides of the diaphragm is equal. The spring pushes the breaker plate to the retarded position.

(2) When the engine is running and manifold vacuum is high, atmospheric pressure pushes the diaphragm against spring pressure and compresses the spring. The movement of the diaphragm pulls the breaker plate to the full advance position. If the engine is then placed under load or if for some other reason manifold vacuum decreases, the spring is able to move the diaphragm and retard the spark.

(3) Although the centrifugal and the vacuum mechanisms do the same thing, they cause spark advance under different conditions. The centrifugal advance is controlled entirely by the engine RPM. The vacuum advance responds to varying loads on the engine. When the load is great there will be little or no vacuum advance, because the throttle valve will be open and the manifold vacuum will be low. Most modern high-speed engines in civilian vehicles use both types of advance mechanisms on their distributors. When both are used the spark advance will respond to both engine speed and load.

Note. - Complete exercises number 104 through 110 before continuing to section III.

104. The capacitor is connected in

a. parallel with the points.
b. series with the points.
c. series-parallel with the points.

105. The distributor points are opened by the cam and closed by

a. spring tension.
b. collapse of the magnetic field.
c. the capacitor discharge.

106. The high-tension wiring used in the ignition system consists of

a. small wires covered by thick insulation.
b. heavy wires covered by thick insulation.
c. heavy wires covered by woven metal shielding.

107. The spark gap between the insulated and grounded electrodes of the spark plug is better known as the

a. space gap.
b. arc gap.
c. air gap.

108. A vehicle that is usually driven at high speeds will probably need spark plugs with a

a. built-in resistor.
b. long insulator nose.
c. short insulator nose.

109. The weight base of the centrifugal advance mechanism is fixed to the distributor

a. drive shaft.
b. cam shaft.
c. breaker plate.

110. On what principle does the distributor advance mechanism used on the Army's tactical wheeled vehicles operate?

a. Centrifugal force
b. Vacuum.
c. Centrifugal-vacuum

## SECTION III. CONCLUSION

7. SUMMARY. In this lesson we have covered the components of the battery ignition system. We have discussed their purpose, construction, and operation. You will need to understand these things before you start to perform maintenance on the system.

8. PRACTICE TASK LIST DIRECTIONS. Appendix A contains a list of tasks associated with ignition systems. They are representative of the tasks you will be required to perform as a wheeled vehicle repairman. Perform all of the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

# APPENDIX A

## PRACTICE TASK LIST

Practice Objectives. After practicing the following tasks you will be able to:

1. Locate the components of the ignition system.
2. Make a visual inspection of the ignition system to determine its completeness and general appearance.

## TASKS.

1. This lesson covered some of the things you need to know about battery ignition systems. To help you remember the points covered in the lesson, you should start applying some of the things we discussed. You can do this by examining the ignition systems on the wheeled vehicles in your unit.

2. Use the ignition wiring diagram from the appropriate 20-series TM to help you trace the ignition system, and examine all of the wires and the connections.

a. Check the battery cables for corrosion and for tight cable connections.

b. Check all of the wires at the ignition switch.

c. Check the harness and wire leading to primary terminal on the distributor.

d. Check the distributor mounting bolt(s).

e. Check to make sure all of the nuts on the secondary wiring are tight. These nuts should be just tight enough to form a waterproof seal at the terminals. Do not overtighten. The nuts are tight enough if you cannot move the wire back and forth at the terminals on the distributor and spark plugs.

f. Use a 13/16 inch deep socket wrench and remove one spark plug. Examine the insulator nose and determine if the plug is too hot or too cold.

3. Inspect and tighten, if necessary, all the engine ground straps.

4. Crank the engine and note whether or not the engine starts quickly and runs smoothly.

5. Check the distributor cover holddown screws. Remember, if they are loose the distributor is not waterproof.

## APPENDIX B

## REFERENCES

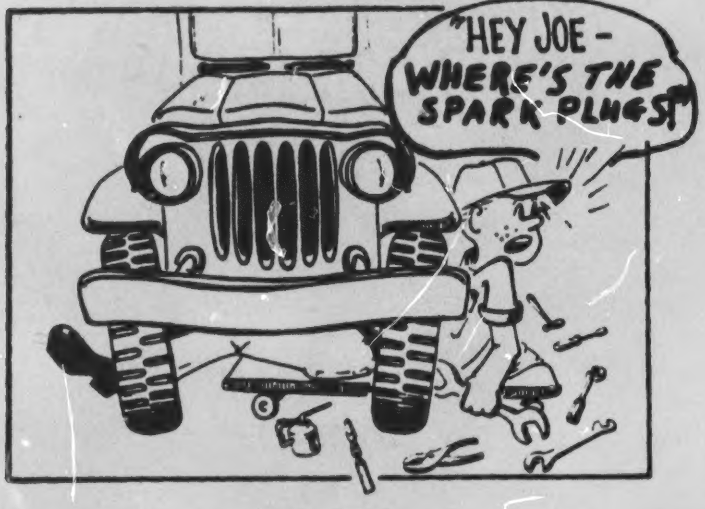
| | | |
|---|---|---|
| TM 9-8000 | Principles of Automotive Vehicles | Jan 56 |

277

ENLISTED MOS

CORRESPONDENCE/OJT COURSE

# ORDNANCE SUBCOURSE 63B203


"HEY JOE - WHERE'S THE SPARK PLUGS?"

# LESSON 7
# REPAIR OF IGNITION SYSTEMS

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

278

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# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

| | |
|---|---|
| **Ordnance Subcourse** 63B203 . . . . | Wheeled Vehicle Electrical Systems |
| **Lesson** 7. . . . . . . . . . . . . . | Repair of Ignition Systems |
| **Credit Hours** . . . . . . . . . . . . | Four |
| **Lesson Objective** . . . . . . . . . . | After studying this lesson you will be able to:<br>1. Describe the procedures for inspecting the ignition system of a wheeled vehicle.<br>2. Explain the procedures for testing the ignition system.<br>3. Describe the procedures used for adjusting and servicing ignition system components.<br>4. Describe the procedures for checking cam dwell.<br>5. Describe the procedures for timing the ignition system. |

6. Explain the procedures for troubleshooting the ignition system.

7. Describe the procedures for removing and replacing the distributor.

| | |
|---|---|
| Study Assignment . . . . . . . . | Study the text and illustrations carefully. It discusses the procedures involved in inspecting, testing, adjusting, and replacing ignition system components. |
| Materials Required . . . . . . . . | All students: Exercise response list and answer sheet.<br>Correspondence/OJT option students: See appendix A. |
| Suggestions . . . . . . . . . . . | Watch an experienced mechanic working on a vehicle's ignition system. If possible, use the knowledge you obtain in this lesson to perform some of the tasks with the mechanic's help. |

## STUDY TEXT

### SECTION I. INSPECTION OF IGNITION SYSTEMS

1. INTRODUCTION. As we drive along our Nation's highways, it is a common sight to see disabled vehicles on the roadside. Repairmen have stated that 60 percent of vehicle breakdowns on the highway are caused by failures in the ignition system. In most cases, a minor tuneup consisting of small parts replacement and adjustment of the ignition system would have prevented the failure.

a. Many repairmen, when troubleshooting the ignition system, have little difficulty in locating the defective component but fail to find the reason the component became defective. For example, let's suppose the repairman finds that an engine is misfiring because the distributor points are badly burned. He corrects the trouble by replacing the points. However, the vehicle is back in the shop one week later with the newly installed points burned as badly as the original set. Where did the repairman go wrong? He did not check thoroughly enough! He cured the immediate trouble by replacing the points, but he did not check to find what caused the points to be bad in the first place. The new points were only a temporary cure, because the reason for the failure of the original points was not found and corrected. In shop language this repairman's actions are known as "curing the effect but not the cause."

b. Never be satisfied when you find something wrong. Find out what caused it to go wrong. In the case of the burned or pitted distributor points one or more of several faults could have been the cause. A shorted or bypassed resistor unit, excessively high generator output voltage, a shorted coil primary winding, a loose or defective capacitor or one of the wrong capacity, a defective ignition switch (one that allowed current to reach the points even when the switch was turned off), improperly adjusted points, or just plain wear (all points eventually burn) are some of the common faults.

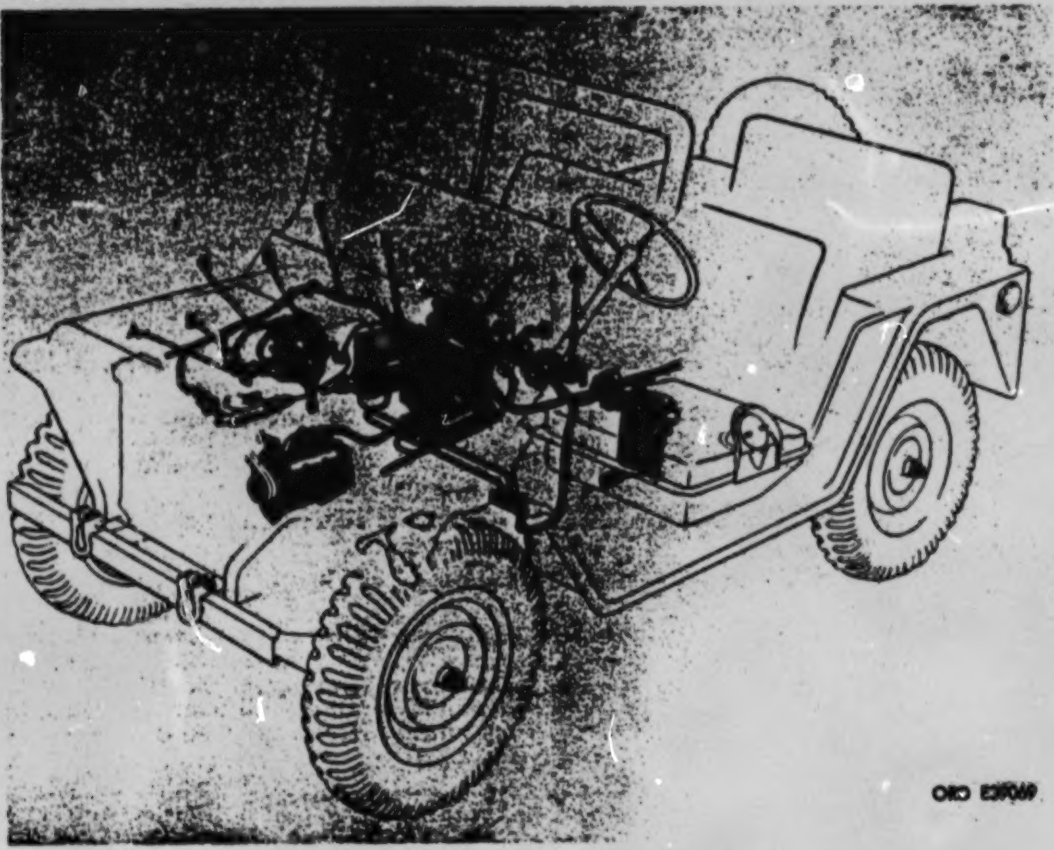
c. In this lesson we will first cover the complete checkout of an ignition system. Then we will discuss specific procedures for locating and correcting troubles that are likely to occur in the system.

2. INSPECTION PROCEDURES. A complete check of the ignition system should be made every time you perform an engine tuneup. A tuneup always includes a check of the three essentials; i.e., compression, ignition, and carburetor. However, ignition is the one that causes the most trouble.

a. The engine compression pressure should always be checked first, because if it is not within acceptable limits checking and adjusting the other two essentials will not make the engine run as it should.

b. Procedures for checking engine compression were described in Subcourse 63B202. The ones for checking the fuel-air system will be described in Subcourse 63B204, so this lesson will be limited to the procedures that apply to the ignition system.

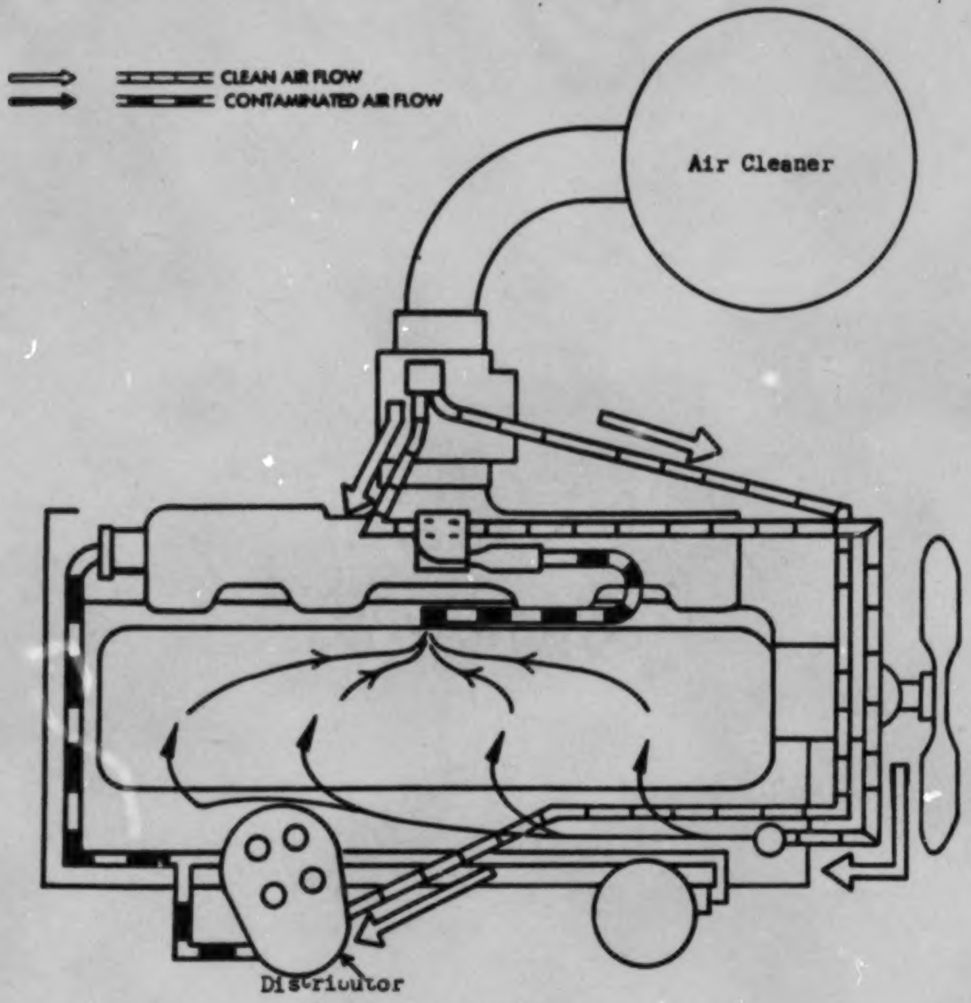
c. In addition to the above a visual inspection of the ignition system should be made. Inspect all visible portions of the ignition system. Look especially for loose or corroded terminals, missing or loose bolts and screws, and improperly placed wires and cables (too close to the exhaust pipe or manifold or wires actually rubbing on metal parts).



*Ignition system*

| Key | Item | Key | |
|---|---|---|---|
| A. | Spark plug | D. | Ignition distributor |
| B. | Housing for radio suppression capacitor | E. | Ignition wiring |
| | | F. | Battery |
| C. | Spark plug cable | G. | Ignition switch |

d. Check the ventilation lines and fittings between the air cleaner, distributor, and intake manifold. These lines are found on the ignition systems of the Army's tactical wheeled vehicles. Sealed vent lines are necessary in order to vent and to remove moisture from the waterproof distributors. Vent lines are not used on the nonwaterproof components of commercial vehicles. Distributors on these vehicles are vented to the outside air by means of a small venthole in the distributor body.


CLEAN AIR FLOW
CONTAMINATED AIR FLOW
Air Cleaner
Distributor

Note. - Complete exercises number 111 and 112 before continuing to section II.

111. The most likely cause of engine breakdowns is the

- a. fuel system.
- b. engine timing.
- c. ignition system.

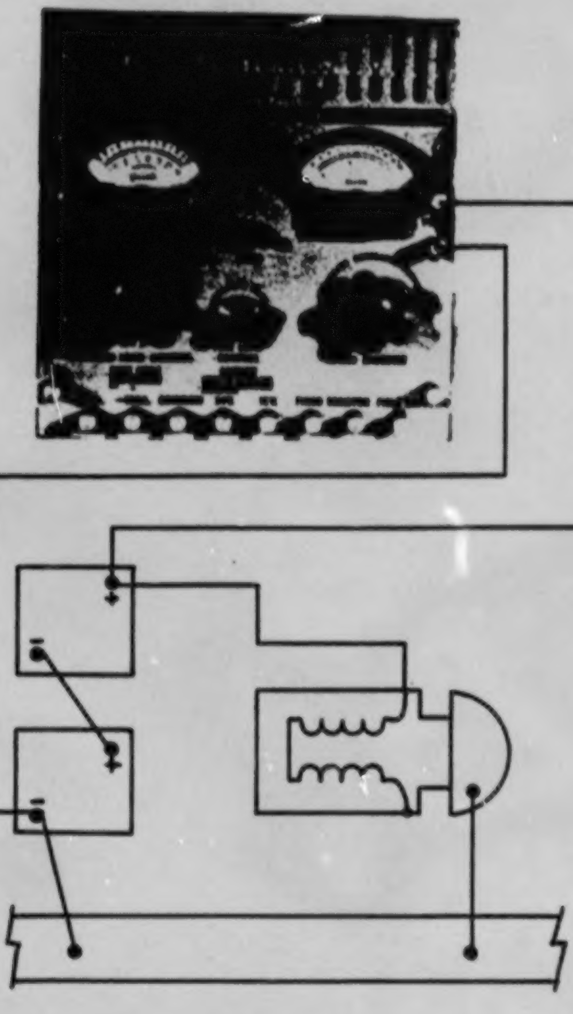
112. The vent lines on the waterproof distributor are designed to

- a. remove moisture.
- b. cool the points.
- c. pressurize the distributor.

## SECTION II. IGNITION SYSTEM MAINTENANCE

**3. IGNITION SYSTEM ELECTRICAL TESTS.** Like the other circuits on the vehicle, the electrical tests on the ignition system begin with the battery. We cannot expect to get maximum output at the coil secondary terminal unless the battery is properly charged. Before making any tests, don't forget to remove watches and rings.

a. Connect the voltmeter of the LVCT across both batteries as shown in the figure.



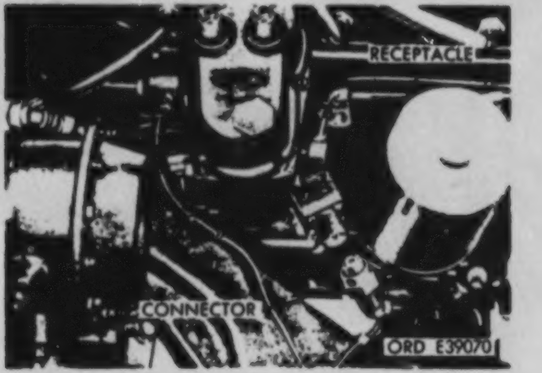
Battery test

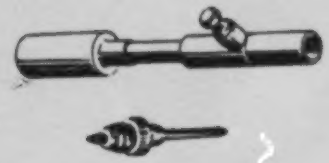
b. Place the voltmeter selector switch in the 50-volt position and the ignition switch in the OFF position. Then close the starter switch. With the starter turning the engine, the voltmeter should not drop below 18.5 volts. If it does, check the batteries with a hydrometer. If the batteries are in a state of discharge, they should be brought up to normal before proceeding with the test. When cranking the engine the ignition system may not get enough current through its primary circuit to build up a satisfactory secondary voltage if the batteries are low. So, be sure the batteries are in good condition.

c. After the batteries are checked, use the following procedure for checking the ignition primary circuit.

(1) Disconnect the primary lead at the distributor.

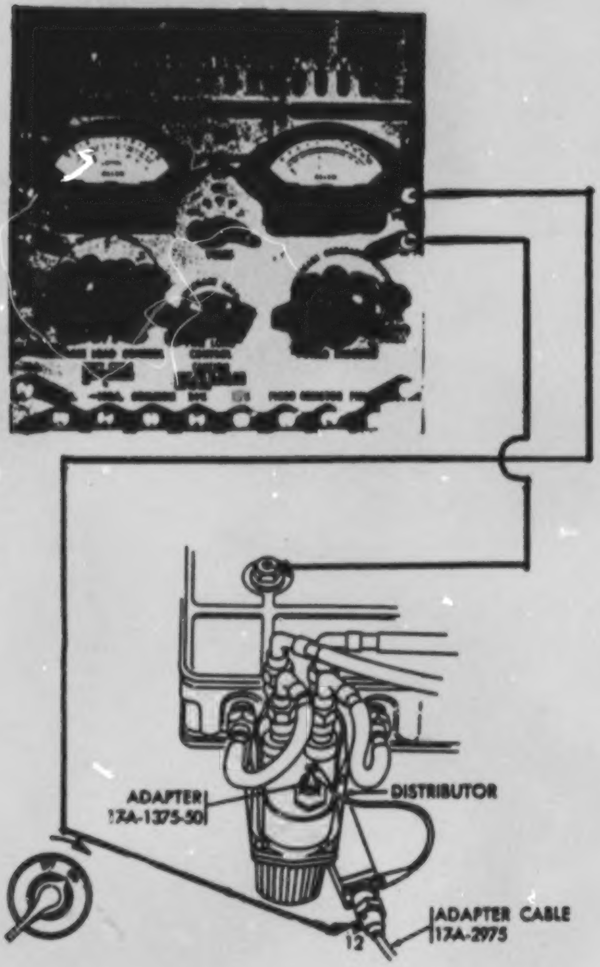
(2) Install the primary adapters and connect the voltmeter of the LVCT across the primary circuit as shown in the figure.





d. Turn the voltmeter selector switch to the 50-volt position and turn on the ignition switch. The voltmeter should read 24 volts. If it does, the circuit is complete between the battery and the primary terminal at the distributor.

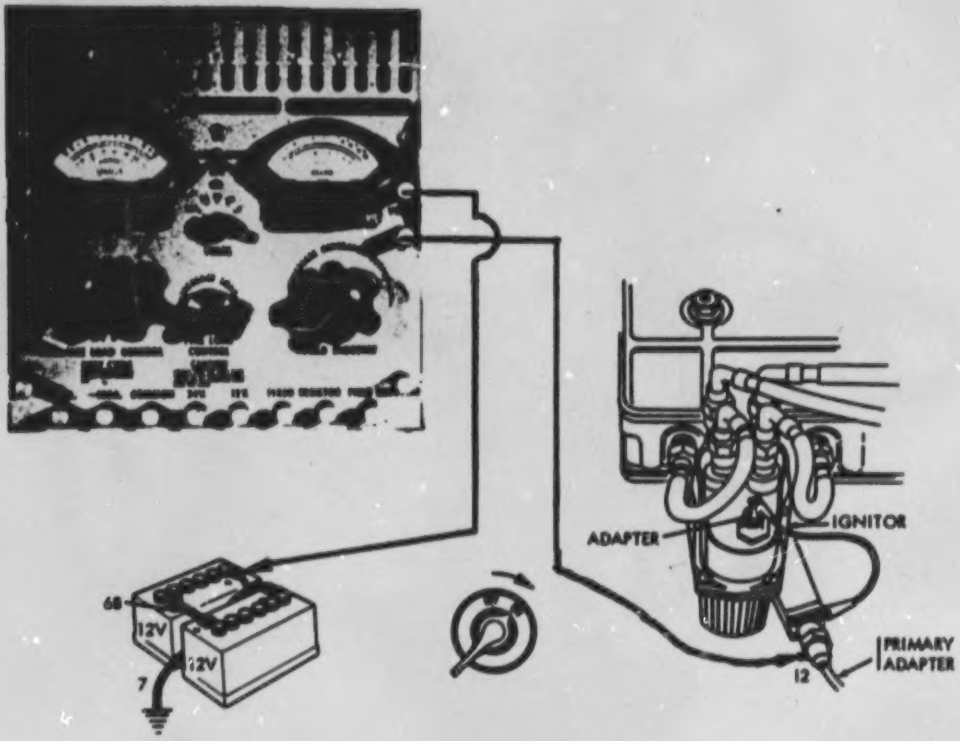
e. If the voltmeter reads zero, connect the positive voltmeter lead to the distributor terminal at the ignition switch. If the meter now reads 24 volts, there is an open circuit between the ignition switch and the primary terminal at the coil. Repair or replace the open circuited wire as necessary. This type of test can be applied to almost any electrical circuit. It is commonly called a continuity check.


ADAPTER
17A-1375-50
DISTRIBUTOR
ADAPTER CABLE
17A-2975
12

Checking voltage to the distributor

f. The primary circuit resistance test is designed to show how good the primary circuit is. If any of the connections between the battery and the distributor are loose or corroded, or if the wires are frayed, this test should reveal the deficiency.

(1) With the voltmeter selector switch in the OFF position, connect the positive voltmeter lead to the positive post of the battery that is not grounded.



PRIMARY CIRCUIT RESISTANCE TEST

(2) Connect the negative voltmeter lead to the lug on the adapter at the distributor primary lead.

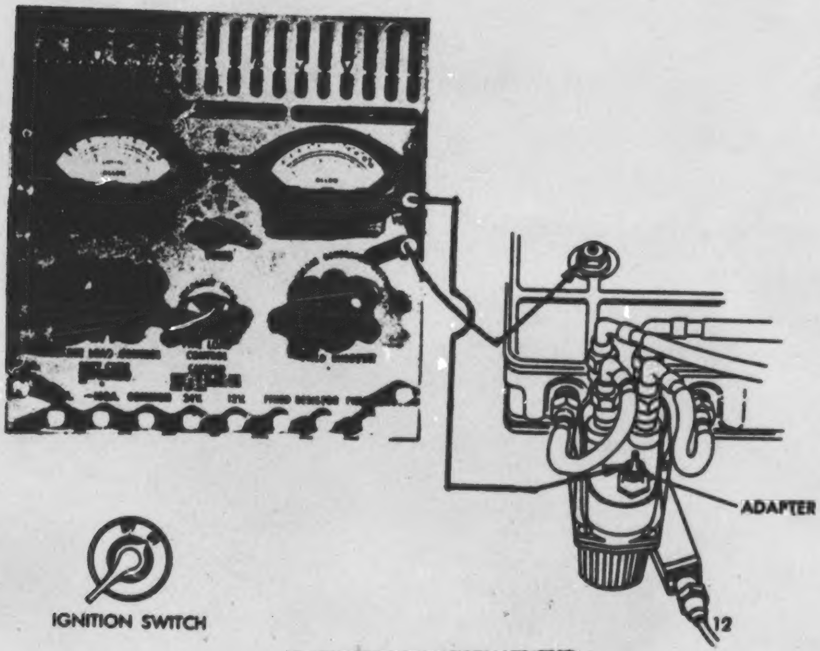
(3) Install the screw adapter in the access hole on top of the distributor. Connect a jumper wire to this adapter and to a good ground on the distributor case. This jumper will make a complete circuit through the coil's primary winding even if the breaker points are open.

(4) Move the voltmeter selector switch on the LVCT to the 50-volt position and close the ignition switch. The voltmeter should read close to zero.

(5) If the voltmeter reads less than 1 volt, move the selector switch to the 1-volt position. If the meter now reads 0.2 volts or less, the circuit between the battery and the distributor is OK. If the meter reads more than 0.2 volt, it indicates a high resistance in the circuit. Look for loose or corroded connections, a defective ignition switch, or frayed wire in the circuit between the battery and the distributor.

g. To perform a breaker point resistance test proceed as follows:

(1) Connect the voltmeter positive lead to the screw-in adapter on top of the distributor and connect the negative lead to a good ground on the engine.



BREAKER POINT RESISTANCE TEST.

(2) Turn the voltmeter selector switch to the 50-volt position and close the ignition switch.

(3) If the voltmeter reads 24 volts, the breaker points are open. Tap the starter switch easily until the meter drops to almost zero volts (points closed).

(4) With the voltmeter indicating approximately zero volts, move the selector switch to the 1-volt position. The reading should be 0.2 volt or less. If it reads more, look for poor connections between the output side of the coil primary and the points. Also look for burned or oxidized points, loose ground point, and a poor distributor plate ground.

(5) In the breaker point resistance test, if the meter reads close to zero when you know the points are open, look for a shorted capacitor or a grounded primary or capacitor lead.

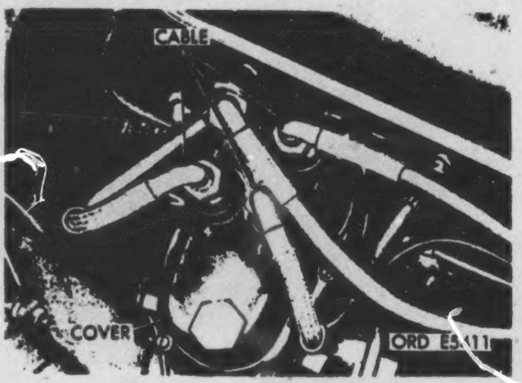
h. During the resistance tests you probably wondered why the voltmeter read so low when the points were closed even though 24 volts were applied to the circuit? Actually what the meter shows is the amount of voltage dropped between the connected points in the tests. Remember that voltage is lost overcoming resistance. In the primary circuit resistance test, the voltmeter indicated that we lost 0.2 volt between the battery and the distributor. This was lost overcoming the resistance in that part of the circuit. If the resistance had been higher, we would have lost more voltage. As the amount of resistance increases, the current flow decreases. This, in turn, would mean a weaker magnetic field in the coil and a weaker spark at the plugs. This type of test is known as a voltage drop test. It can be performed on almost any type of circuit. Remember, however, that any circuit being tested for voltage drop must have current flowing through it.

4. ADJUSTING AND SERVICING IGNITION SYSTEM COMPONENTS. Even when the tests just described indicate the distributor's primary circuit is OK, you should remove the distributor cover and check further whenever you perform an engine tuneup. Such a check will enable you to determine the condition of the rubbing block, breaker point pivot post, etc.

a. With the cover removed you can check components in the secondary circuit also. Examine such things as the rotor, distributor cap, and the coil for evidence of burned contacts, carbon runners, or cracks.

b. The examination may indicate that some parts have to be removed. Here is how it is done:

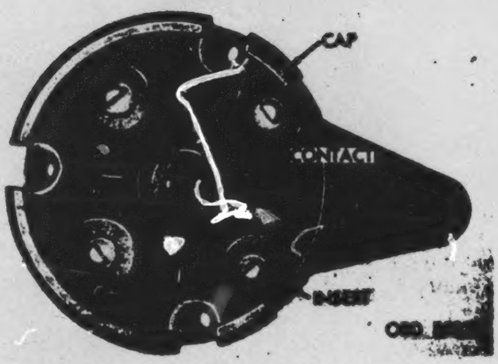
(1) Using a 3/4-inch end wrench, or a "crows-foot" wrench, unscrew the spark plug cable nuts on top of the distributor. Be sure to mark the cables so they can be reinstalled in the correct terminals.



(2) Remove the six slotted head screws that secure the distributor cover to the distributor body.

(3) Lift the cover straight up to avoid damage to the cap, coil, and rotor.

(4) Remove the three screws that secure the distributor cap to the cover. Inspect the cap for evidence of carbon runners or cracks.

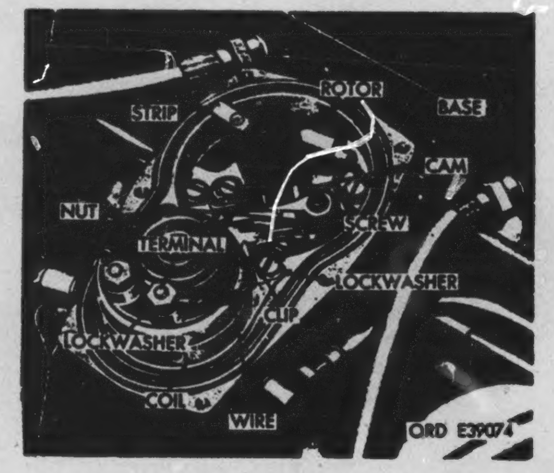

CAP
CONTACT
INSERT
ORD

Distributor cap.

(a) Check the condition of the carbon contact, spring contact, and the spark plug terminal inserts in the cap.

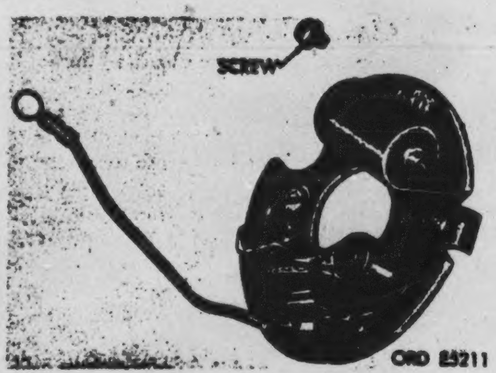
(b) Remove the rotor and check it for cracks and for evidence of arcing or looseness of the contact strip.

c. Check the primary wiring and the distributor points.


STRIP
ROTOR
BASE
CAM
NUT
SCREW
TERMINAL
LOCKWASHER
CLIP
LOCKWASHER
COIL
WIRE
ORD E39074

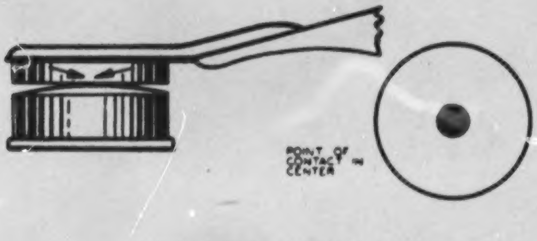
(1) Examine the points for any evidence of burning, pitting, or for failure to make full face contact. Points that have a light, greyish coloring are serviceable, provided they are not pitted. If, however, they have a bluish-black coloring, or if they are pitted, replace them.

(2) This figure shows the breaker plate removed from the distributor. It is easier to replace the points if this plate is removed. The plate is held in place by two screws and two spring-loaded clips.

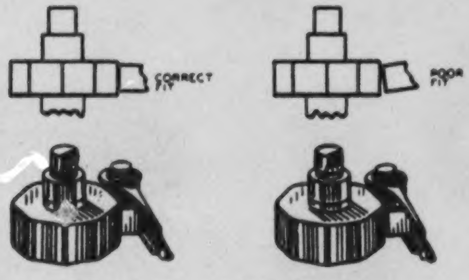

SCREW
ORD E3211

(3) To replace the points, loosen the screw that holds the breaker arm spring to the primary terminal. Lift the movable breaker arm straight up until it clears the pivot post. Remove the lock screw and lift the ground point off of the pivot post and the eccentric screw.

(4) To install new points, reverse the procedures described above. Use extra care to see that the contacts and the rubbing block are properly alined.



*Correct Point of Electrical Contact*

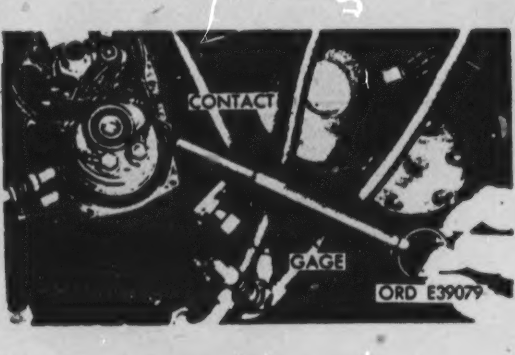


*Right and Wrong Rubbing Block Fit*

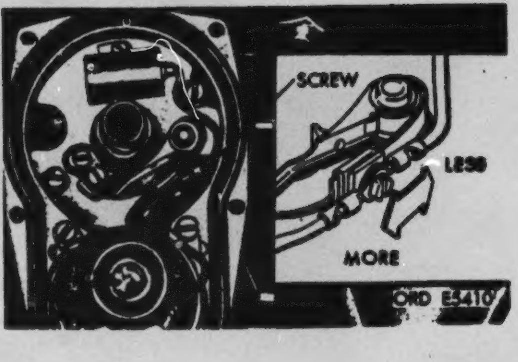
(5) Put a very light coat of distributor cam lubricant or petroleum jelly on the cam lobes that contact the rubbing block on the movable point. Be careful not to put too much lube on the cam. The excess may get on the points and ruin them.

(6) Test the centrifugal advance mechanism by turning the cam in the direction it rotates. It should move about 15°. Release the cam. It should snap back to its retarded position. If it doesn't snap back, the advance mechanism is sticking or the springs are weak. To correct this condition at organizational maintenance level, replace the distributor.

(7) The spring tension of the points should be checked. Be sure the rubbing block is not touching one of the cam lobes and then hook the spring tension gage to the movable point. Pull at right angles to the movable point. At the instant the points separate, the spring scale should indicate from 17 to 20 ounces of tension.

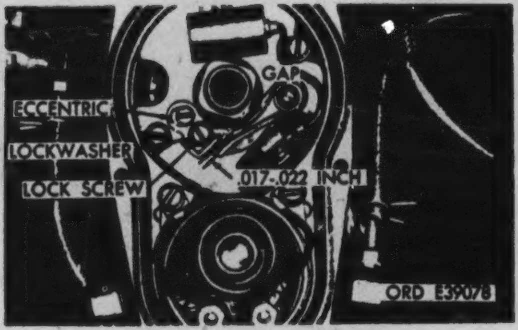


(8) To adjust the tension, loosen the screw at the primary terminal and slide the spring to the right if the tension is too great. If less than 17 ounces, slide the spring to the left. The spring tension adjustment is critical. (The tension on some points is adjusted by bending the spring.) If the tension is excessive, the rubbing block will wear rapidly and the points will tend to pound together. If there is not enough spring tension, the points will close slowly and will probably cause the engine to miss at high speeds.



(9) To adjust the point gap clearance, rotate the engine until the rubbing block is resting against one of the four high points (lobes) of the cam. A flat feeler gage may be used to adjust the points if they are new. If they are old, use a wire-type feeler gage.

(10) Loosen the lock screw on the stationary point. Move the eccentric screw backward or forward until a .017 to .022 feeler blade can be pulled, with a slight drag, from between the points without moving them. This too is a critical adjustment, so be sure you gage the points accurately. If the points are too close, they will burn; if too wide the engine will miss—if it runs at all. After the points are adjusted, tighten the lock screw. Then check the point gap again to make sure it did not change when you tightened the screw.



(11) For some vehicles, such as the 1/4-ton truck M151, the distributor points may come as part of a repair kit. The kit will also include a new capacitor. To install the capacitor, remove the screw that secures it to the distributor plate. Also remove the screw that attaches the pigtail lead to the primary terminal. Always replace the capacitor before you check the breaker point spring tension because the primary terminal screw anchors both the spring and the capacitor's pigtail lead.

(12) Put a few drops of lubricating oil on the felt wick in the cam before you install the rotor on top of the cam. When you install the rotor, be sure it is correctly alined with the cam and that it seats snugly on it.

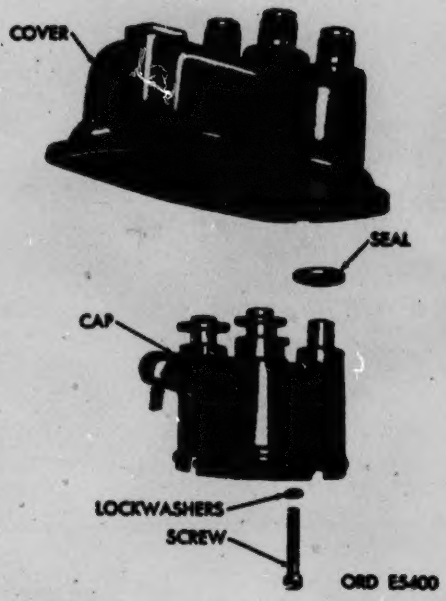
(13) Inspect the "O" ring seal that fits in a groove in the distributor body. Be sure it is in good condition and properly seated in its groove. Otherwise the distributor will not be waterproof.

(14) Replace the distributor cap seals, if necessary, and install the cap in the distributor cover.

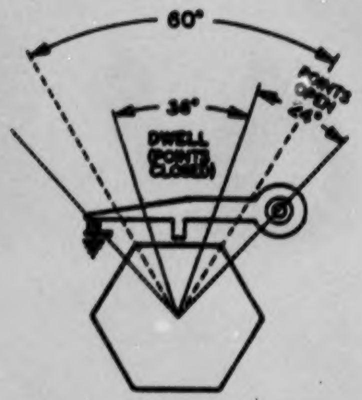
(15) Install the cover and cap assembly on the distributor body. Be sure to lower the cover straight down on the distributor body, for otherwise the contact spring that makes the electrical connection at the coil's secondary terminal may be bent.

(16) Install the spark plug wires in their proper terminals. Tighten the nuts at the ends of the wires just enough for the rubber grommets to seat. Do not overtighten.

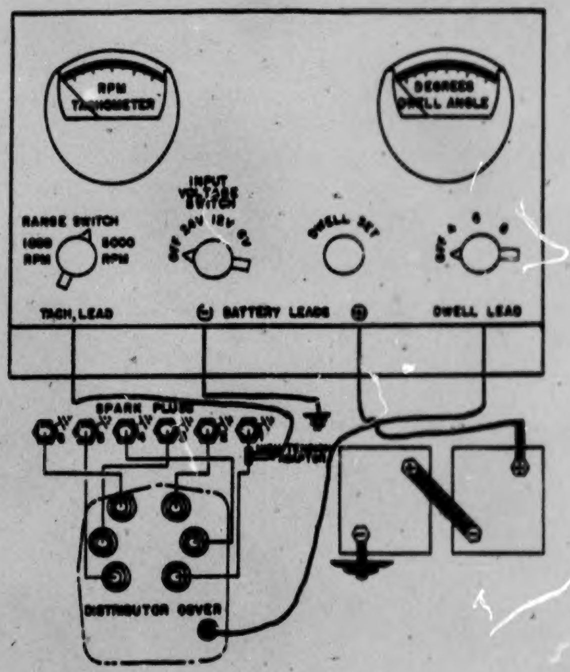
**5. CHECKING THE CAM DWELL.** With the distributor reassembled our next step is the ignition point dwell test. This test will tell us several things about the adjustment of the points, action of the breaker point spring, the condition of the cam lobes, and whether or not the cam shaft bushings are worn or if the shaft is bent.



a. By definition the point dwell is the number of degrees the cam rotates while the points are closed. Point dwell is also known as cam angle or degrees of dwell. On a 4-cylinder engine the dwell is from 39° to 45°. On engines with more cylinders the dwell will be less. The amount of dwell on any engine is changed by increasing or decreasing the breaker point gap. The figure illustrates the cam dwell of a 6-cylinder engine. Notice that the six lobes on the cam are 60° apart. The total time the points are closed (36°) plus the time they are open (24°) equals 60°. On a 4-cylinder engine the total is 90° since the lobes are 90° apart.


60°
36°
DWELL (POINTS CLOSED)
POINTS OPEN 24°

b. This figure shows the tachometer-dwellmeter connected to the waterproof distributor on a 6-cylinder engine. It would be connected in exactly the same way on any military wheeled vehicle engine that has a waterproof distributor.


RPM TACHOMETER
DEGREES DWELL ANGLE
INPUT VOLTAGE SWITCH
RANGE SWITCH
1000 RPM
5000 RPM
OFF 24V 12V 6V
DWELL SET
OFF 4 6 8
TACH. LEAD
BATTERY LEADS
DWELL LEAD
SPARK PLUGS
DISTRIBUTOR COVER

(1) With the meters connected as shown in the accompanying figure, turn the input voltage switch to the 24-volt position.

(2) Turn the dwell switch to the number that matches the number of cylinders in the engine—in this case number 6. Turn the ignition switch on. If the dwellmeter fails to register on the scale, the points are open. Turn the engine until a reading is obtained on the dwellmeter.

(3) Move the dwell set knob back and forth until the dwellmeter needle moves all of the way to the right-hand side of the scale. Be sure that the needle lines up exactly with the last graduation on the scale.

(4) Crank the engine and allow it to run at idle speed. Note the reading on the dwellmeter. The needle should be steady and indicate between 39° and 44° on a 4-cylinder engine.

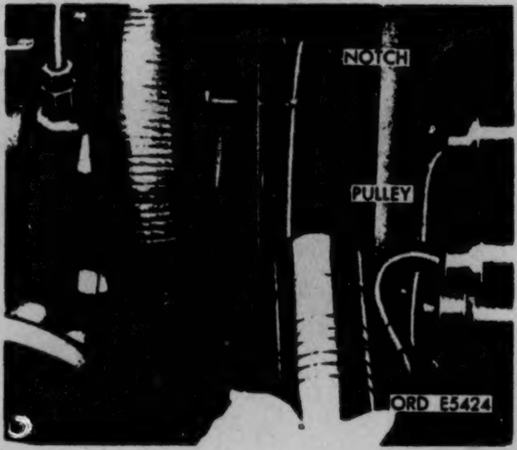
(5) If the needle is not steady, look for a bent distributor shaft, worn cam lobes, or worn shaft bushings. Also look for binding on the pivot post by the movable point.

(6) If the needle is steady and indicates the correct amount of dwell, the point adjustment is OK. If a high reading is obtained, the points are too close. To reduce the dwell, increase the point gap. To increase the dwell, reduce the point gap.

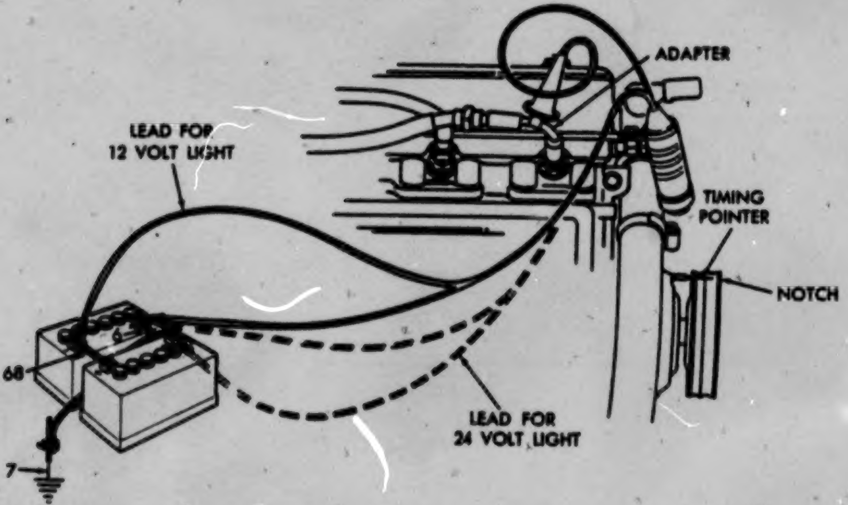
(7) Now speed up the engine until the tachometer registers 2,500 RPM. The needle on the dwellmeter should move to the left. The needle should not, however, move more than 2°. In other words, if it indicated 39° at idle speed, it should indicate at least 37° at 2,500 RPM. If it drops more than 2° on the scale, recheck the point spring tension. It is probably too weak and is not closing the points fast enough.

6. CHECKING THE IGNITION TIMING. Timing the distributor to the engine is always done after the point dwell has been set. Never reverse this procedure, because any change in the point setting will change the ignition timing.

a. On all Army tactical wheeled vehicles the ignition timing marks are on the crankshaft pulley or vibration damper. A stationary pointer is mounted on the front of the engine. On some engines there is a single notch on the pulley. On other engines there may be a series of marks graduated in degrees of crankshaft rotation.


NOTCH
PULLEY
ORD E5424

b. To check the ignition timing, connect the battery leads of the timing light to the positive and negative posts on the battery. Disconnect the high-tension cable at the number 1 spark plug and install the cable adapter. Then connect the high-tension lead of the timing light to the adapter.


ADAPTER
LEAD FOR 12 VOLT LIGHT
TIMING POINTER
NOTCH
68
7
LEAD FOR 24 VOLT LIGHT

298

c. Crank the engine and allow it to run at idle speed. Aim the light at the timing mark the same way you would aim a rifle. Line it up so that your eye, the light, the pointer, and the notch on the pulley form a straight line. But be careful! Be sure that neither you nor the light touch the fan or the drive belts.

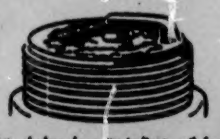
d. With the light correctly aimed, the notch should exactly line up with the pointer every time the light flashes. On the 1/4-ton truck the notch is set 6° before TDC.

e. If the timing mark does not line up with the pointer, loosen the screw that secures the distributor to its mounting bracket. Slowly rotate the distributor back and forth until the timing mark is alined. Retighten the screw.

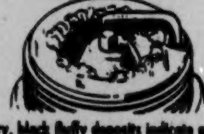
f. Now speed up the engine. The notch on the crankshaft pulley should move counterclockwise. If it doesn't, the spark advance mechanism is not working. If you can't free up the advance mechanism, replace the distributor. The engine will not develop much power if the advance doesn't work.

7. SERVICING THE SPARK PLUGS. When performing an engine tuneup, the best time to service the spark plugs is immediately after you check the engine compression. The spark plugs had to be removed in order to make the compression test, but do not leave them out of the engine very long. Dust, dirt, nuts, and washers can fall into the open spark plug holes in the cylinder head, so reinstall the plugs as soon as possible.

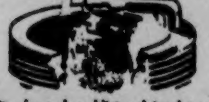
a. Examine the spark plug porcelains, electrodes, and threads carefully. The conditions around the electrodes can tell us a lot about the condition of the engine and the way it is being operated. Study the symptoms illustrated and described in the figure. If the plugs are obviously too hot or too cold for the engine, replace them with plugs of the proper heat range.



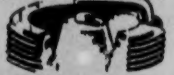
Wet, sludgy deposits indicate oil fouling. Go to the hotter plug unless your engine is to be changed.



Dry, black fluffy deposits indicate gas fouling. Adjust carburetor idle mixture. If you still have gas fouling, change carburetors. (Be sure drivers are not overchoking.)



White, burned or blistered insulator nose and badly eroded electrodes mean the plug's too hot. Go to colder plug.



Rusty-brown, greyish tan or white powdery deposits, electrodes only mildly eroded, indicate everything's fine. Carry on with the plugs you have.

b. To clean the spark plugs, wash them first in drycleaning solvent. Then use a compressed air nozzle to blow them dry.

c. Finally clean the spark plug porcelains and electrodes in a sand-blast cleaner. Place the plug in the rubber grommet and move the knob to the abrasive blast position. Do not operate the abrasive blast for more than 5 seconds or you may damage the procelain on the insulator nose. Rotate the plug with your fingers while the blast is being applied.

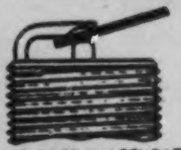
A—AIR-BLASTING

B—ABRASIVE-BLASTING

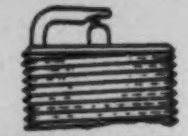
d. After the abrasive blast, shift the control lever to the airblast position to blow all of the grit out of the base of the spark plug.

e. If the electrodes are oxidized, dress them up with a point file.

f. Use a wire gage and adjust the airgap to between .028" and .032" on the 1/4-ton truck. The reason for using a wire gage on electrodes is clearly illustrated in the figure. They do not wear evenly so they cannot be accurately adjusted with a flat-type feeler gage. Be sure you bend nothing but the grounded electrode when you adjust the plugs.



FLAT GAGE-INACCURATE



ROUND GAGE-ACCURATE

MEASUREMENT GAGES

g. After the plugs have been cleaned and regapped, install new gaskets over the lower threads and reinstall the plugs in the cylinder head. Use a torque wrench and tighten the plugs to about 20 lb-ft. Then install the distributor to spark plug high-tension cables.

8. TROUBLESHOOTING THE IGNITION SYSTEM. During an engine tuneup the complete ignition system is checked and renewed or adjusted as necessary. In troubleshooting the system, however, we do only what is necessary to locate and correct the cause and the effect of any malfunction or failure in the system. In other words, we try to isolate and correct any faults as well as their causes.

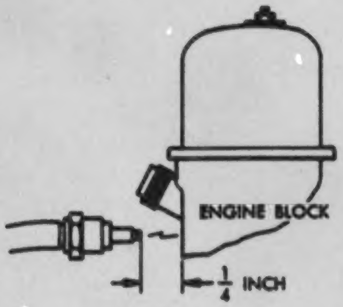
a. If an engine fails to start or misses after it starts, it is necessary first of all to make sure the trouble is in the ignition system. If fuel is reaching the carburetor and if the engine's compression pressure is known to be satisfactory, then troubleshoot the ignition system. Follow the troubleshooting procedures described below to locate the cause of the failure in the system.

(1) Disconnect the spark plug wire at any one of the spark plugs.

(2) Hold the end of the wire about 1/4 inch away from the engine block.

(3) Have an assistant turn on the ignition switch and step on the starter.

(4) A strong bluish-colored spark should arc across the gap between the wire and the engine block. If the spark is weak, it will have an orange color.



SECONDARY CURRENT TEST

(5) Repeat this test at several of the spark plugs. If a weak, orange-colored spark is obtained at each spark plug wire, the trouble is probably in the distributor. However, if all of the wires tested delivered a strong blue spark except one, replace that wire and test it again. If you now get a good spark, the trouble was in the wire you replaced.

(6) If all of the wires deliver a strong blue spark, but the engine still misses, remove the wires from the spark plugs one at a time while the engine is running. If, as each wire in turn is removed from the plug the engine rhythm changes, the plug is firing OK. On the other hand, if there is no change in engine rhythm when a wire is removed, then the plug is probably not firing.

(7) Remove any spark plug that is not firing. Compare the condition of its electrodes and porcelain with the plugs illustrated earlier in the lesson. If your spark plug cleaner has a spark plug tester, clean, adjust, and test the plug. If you do not have a tester, install a spark plug that is known to be good. Crank the engine and check to see if removing the wire from the new plug changes the rhythm of the engine. If the rhythm changes, the plug is firing.

b. If an orange-colored spark was obtained at several or all of the spark plug wires, check the distributor. On military vehicles with their waterproof systems, make your external checks first.

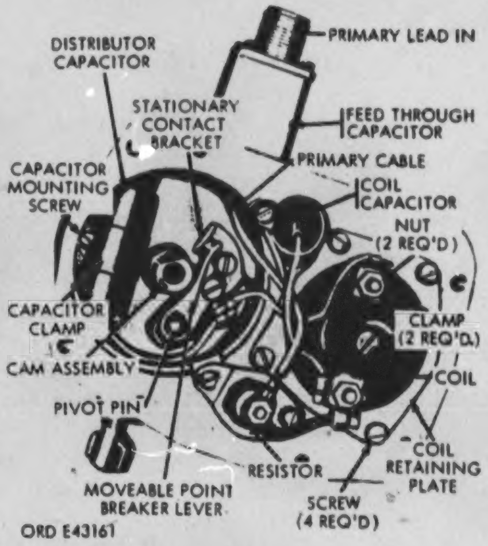
(1) Inspect the primary circuit wiring from the battery to the distributor. Perform the voltage drop tests, already described, on the entire primary circuit. If it checks OK, remove the distributor cover and cap.

(2) Distributor points that are burned or improperly adjusted can be the reason for the weak spark at the plugs, so check them first. Don't forget to check the spring tension, the pivot post (points binding), and the rubbing block.

(3) If there is a large buildup of metal on one point and a corresponding pit or cavity on the other point, the capacitor is probably defective. If in doubt as to the condition of the capacitor, replace it. Don't forget, however, that if the generator output voltage is too high, the ignition points will be burned and pitted also. Check the charging voltage if you're in doubt.

(4) One thing found in all 12- and 24-volt ignition systems that has not been previously mentioned, is a resistor. In the Autolite system used on the 1/4-ton trucks, the resistor is located inside the ignition coil.

(5) In the Delco system, the resistor is installed in the primary circuit on the battery side of the coil. All of these resistors reduce the amount of voltage applied to the primary winding in the coil and to the points. If the resistor is open, no current can flow through the primary circuit. If it is shorted (adjacent coils of the resistor wire touching each other), too much current can flow in the primary circuit and damage the coil and the points. The resistor for the Autolite distributor is built into the coil and cannot be checked at organizational level. The Delco can be checked by making an inspection of the resistor and a continuity check with the LVCT as previously described.


DISTRIBUTOR CAPACITOR
PRIMARY LEAD IN
STATIONARY CONTACT BRACKET
FEED THROUGH CAPACITOR
PRIMARY CABLE
CAPACITOR MOUNTING SCREW
COIL CAPACITOR
NUT (2 REQ'D)
CAPACITOR CLAMP
CLAMP (2 REQ'D.)
CAM ASSEMBLY
COIL
PIVOT PIN
COIL RETAINING PLATE
RESISTOR
MOVEABLE POINT BREAKER LEVER
SCREW (4 REQ'D)

ORD E43161

c. There are also possible defects in the secondary circuit that can be the cause of a weak spark at the plugs. Cracks in the distributor cap or rotor can cause this condition, although such cracks, or carbon runners, are more likely to cause zero voltage to be delivered to the spark plugs. Carefully check the cap and rotor. Don't forget to look inside the towers on the distributor cap. They should be free of excessive corrosion. Also check the spring contacts and the carbon brush in the distributor cap. To make the above checks, the distributor cover must be removed.

d. If the distributor cap and rotor are OK, check the output of the coil's secondary winding before you install the cap on the distributor. To do this, insert one end of a spark plug wire in the secondary terminal of the coil. Hold the other end of the wire 1/4 inch from the engine block. Have your buddy turn on the ignition switch and step on the starter pedal. A strong blue spark should jump the 1/4-inch gap to the engine block. If it doesn't, replace the coil and repeat the test. If you get a strong spark now, install the rotor, distributor cap, cover, and wiring. If you do not get a strong spark with the new coil, repeat all tests you have previously made. Somewhere along the line you missed something.

e. There are a few precautions you should always take when testing ignition system components. Some of the more important ones are listed below.

(1) Never leave the ignition switch on unless the engine is being cranked or it is running. It won't take long to burn up the points if the switch and the points are both closed. The exception to this rule is if you are checking the voltage drop across the points - but don't take long to do that!

(2) Never bypass the resistor with a jumper wire to the coil. The applied voltage to the coil and to the points will be close to battery voltage if the resistor is bypassed. This much voltage will destroy the coil and the points.

(3) Never check the points with the ignition switch closed unless the capacitor is connected to the circuit. Remember, the capacitor is used to prevent arcing across the points when they open.

(4) Be sure all parts are dry and free of grease, except for oil on the wick in the cam and grease on the cam lobes.

(5) Never perform any test using the 1-volt scale on the LVCT until you have first obtained a low reading on all other scales as you work, range by range, toward the 1-volt position.

(6) Never use a feeler gage on the points unless the ignition switch is turned off or the circuit is broken elsewhere.

f. There is one final component that may cause some ignition trouble. It is the feed-through capacitor through which the primary circuit flows. Its purpose is to provide radio interference suppression. However, it should not interfere with the primary circuit. To check it, make a continuity check at the input terminal of the distributor. Then repeat the check at the terminal on the primary wire leading from the feed-through capacitor. If you fail to get a voltage reading on the wire from the capacitor, but you got a 40-volt reading at the distributor input, replace the capacitor.

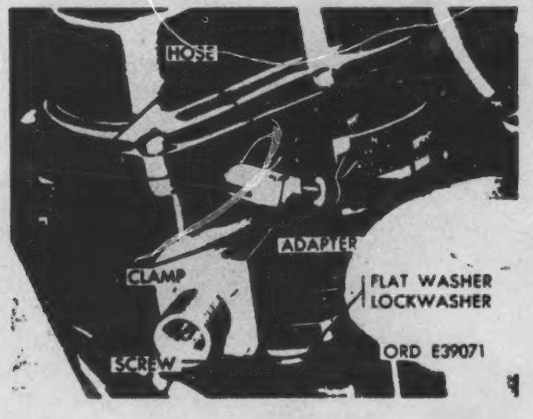
9. DISTRIBUTOR REPLACEMENT. We have mentioned previously in this lesson that the distributor might have to be replaced, so let's see how this is done.

a. First, let's see just how you should go about removing the distributor.

(1) While it is not absolutely necessary, it is a good idea to first turn the engine until the number 1 piston is on the compression stroke and the timing marks alined.

(2) It is also a good idea to next mark the distributor cover to identify the spark plug cables for installation. After this, remove the cables.

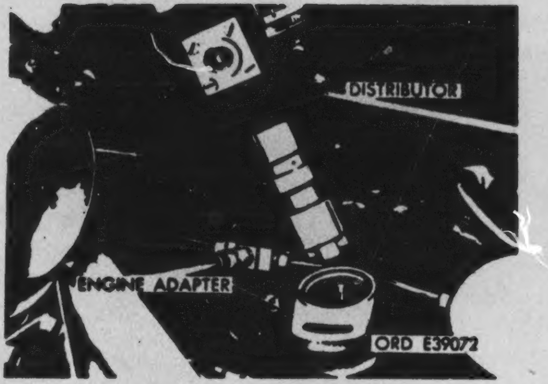
(3) Disconnect the primary cable at the receptacle.



(4) The vent hoses can be removed next; then remove the distributor mounting screw located at the slotted hole in the adapter.

(5) Now lift the distributor out of the adapter.

b. The procedures for installing the distributor are the reverse for removing it, except that we have timing to worry about, so let's see what these procedures are.

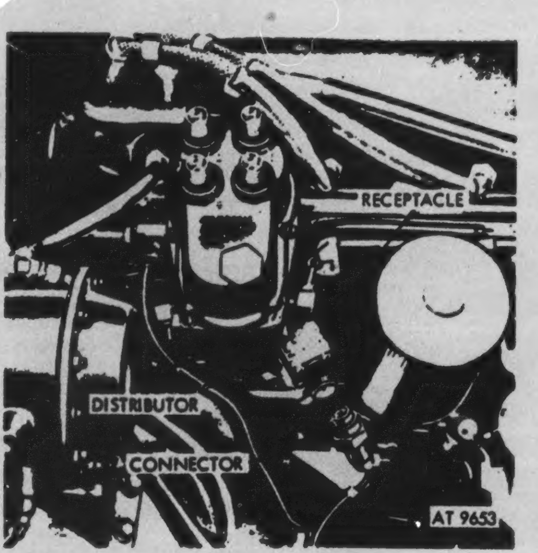


(1) To make installation and timing a little easier, remove the distributor cover.

(2) Turn the rotor so that it is positioned pointing toward where the outlet for the number 1 spark plug wire will be when the cover is installed. If the engine was not previously turned so the timing marks are alined and the number 1 cylinder is on the compression stroke, do this now.

(3) Install the distributor in the adapter in the position shown in the figure. Carefully turn the distributor and shaft back and forth until the drive tang on the distributor shaft drops into and bottoms in the drive slot in the intermediate shaft. This drive tang is offset so it should only go in one way. When the distributor seats, with the engine positioned as described earlier, the rotor should be pointing to where the number 1 plug wire will go.

(4) Next, install the distributor mounting screw (do not tighten) then turn the distributor clockwise, continue to slowly turn it counterclockwise until the breaker points just start to open.



(5) After the above has been done, tighten the distributor to adapter screw and install the cap and cover assembly, spark plug wires, vent lines, and primary leads.

(6) The above procedures only roughly time the engine but they are enough so that it will run. The timing must still be checked and adjusted as described earlier in this lesson.

Note. - Complete exercises number 113 through 130 before continuing to section III.

113. Before checking the ignition system, the battery voltage should be checked with the

a. ignition switch on.
b. starter motor turning.
c. electrical circuits open.

114. When making a continuity check at the input terminal of the distributor, the ignition switch must be

a. open.
b. bypassed.
c. closed.

115. Before using the 1-volt scale on the LVCT to check voltage drop on military wheeled vehicle ignition systems, a check should be made with the voltmeter selector switch in the

a. 50-volt position.
b. 20-volt position.
c. 10-volt position.

116. If the voltmeter is connected across the breaker points (voltage drop test) and the ignition switch is closed, what is indicated if the meter reads 24 volts?

a. Grounded capacitor lead
b. Points are open
c. Points are closed

117. What is indicated if the dwell meter moves $5^{\circ}$ to the left when the engine is speeded up?

a. Advance mechanism is operating
b. Point spring tension is too weak
c. Point gap is too wide

118. What is indicated by an excessively high reading on the dwell meter?

   a. Point gap too close
   b. Too much spring tension
   c. Point gap too wide

119. The ignition timing marks on military wheeled vehicles are located on the crankshaft pulley or the

   a. camshaft gear.
   b. flywheel.
   c. vibration damper.

120. When timing the engine, the high-tension adapter is connected to the spark plug wire leading to cylinder number

   a. 3.
   b. 2.
   c. 1.

121. When checking the ignition timing, what is indicated if the timing mark remains alined with the pointer when the engine is speeded up?

   a. Advance mechanism not working
   b. Engine is perfectly timed
   c. Point spring tension too weak

122. Light brown or grey deposits on the insulator nose of a spark plug indicate the plug is

   a. too hot.
   b. too cold.
   c. normal.

123. What will probably happen to a spark plug that is too cold for the engine?

   a. Electrodes will wear rapidly
   b. Plug will foul
   c. Porcelain will blister

124. The spark plug gap is adjusted by

   a. filing the electrodes.
   b. bending the insulated electrode.
   c. bending the ground electrode.

125. If the engine cranks at normal speed but fails to start, what should be checked?

   a. Spark at the spark plug
   b. Distributor input voltage
   c. Battery cables

126. When holding the spark plug wire 1/4 inch away from the cylinder block, what color should the spark be if it is satisfactory?

   a. Orange
   b. Red
   c. Blue

127. The resistor used in the Delco distributor is located

   a. inside the coil.
   b. on the battery side of coil.
   c. on the point side of the coil.

128. What must be done on vehicles equipped with a waterproof ignition system to check the secondary output of the coil?

   a. Ground out the spark plugs
   b. Remove the distributor cover
   c. Connect the voltmeter to the distributor input

129. The purpose of the feed through capacitor is to

   a. protect the breaker points.
   b. provide radio interference suppression.
   c. speed the collapse of the coil's magnetic field.

130. What must be done after installing a distributor on the engine of an M151 1/4-ton truck?

   a. Adjust the point opening
   b. Check the ignition timing
   c. Install the spark plugs

## SECTION III. CONCLUSION

10. SUMMARY. Learning to perform all of the tests on an ignition system is a lot like learning to play a piano. Nobody does either job very well without a lot of practice. So practice testing the ignition system—and other electrical systems for that matter—every chance you get, until you can make the tests almost automatically. Good electrical troubleshooters are scarce in any maintenance shop. If you really become good at it, you've got it made either in the Army or in civilian life.

11. PRACTICE TASK LIST DIRECTIONS. Appendix A contains a list of tasks associated with the repair of ignition systems. They are representative of the tasks you will be required to perform as a wheeled vehicle repairman. Perform all of the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

# APPENDIX A

## PRACTICE TASK LIST

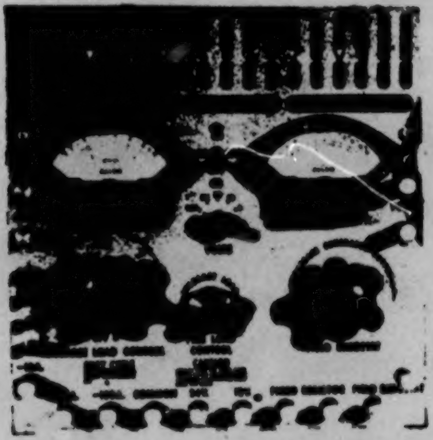
**Practice Objective.** - After practicing the following tasks you will be able to:

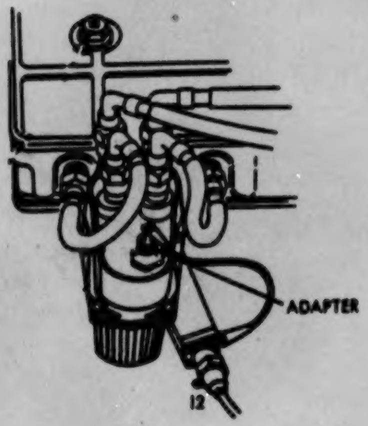
1. Perform a primary circuit resistance test.
2. Perform a breaker point resistance test.
3. Perform a breaker point dwell test.
4. Check the ignition timing.

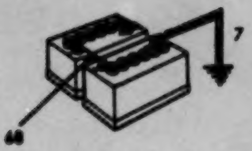
**Tasks.**

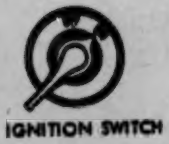
1. Before making the tests on the vehicle, review the lesson. Then to be sure you understand how the test equipment should be connected, draw in the leads as required for the following tests.

a. Draw in the meter leads as they should be to make a primary resistance test. After you have drawn in the leads, refer to the lesson and see if you are correct.



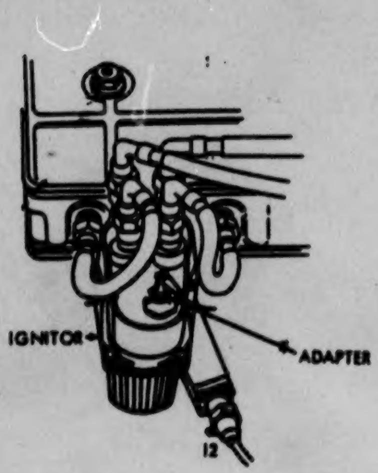






b. Draw in the meter leads as they should be to make a breaker point resistance test. After you have drawn in the leads, refer to the lesson and see if you are correct.

IGNITION SWITCH


IGNITOR
ADAPTER
12

2. In order to practice the tasks listed here, you will need a low-voltage circuit tester, tachometer, dwellmeter, adapter set, and one of your company vehicles that has a spark ignition engine.

3. Perform the primary circuit resistance test.

   a. Install the adapters.

   b. Place the voltmeter selector switch in the 50-volt position.

   c. Connect the voltmeter leads.

   d. Turn on the ignition switch.

   e. Progressively move the voltmeter selector switch down to the 1-volt position.

   f. Interpret the readings obtained at each position of the voltmeter selector switch.

4. Perform the breaker point resistance test.

   a. Install the adapter in the distributor cover.

   b. Place the voltmeter selector switch in the 50-volt position.

   c. Connect the voltmeter leads.

   d. Turn on the ignition switch.

   e. Operate the starter to close the points if the voltmeter reads battery voltage.

   f. Progressively move the voltmeter down to the 1-volt position.

   g. Interpret the voltmeter reading at each position of the voltmeter selector switch.

5. Perform the breaker point dwell tests.

   a. Connect the dwellmeter and tachometer to the vehicle batteries if necessary. (Some dwellmeters include their own batteries and do not require this step.)

   b. Connect the tachometer to the primary adapter if it is operated by the primary circuit. Connect it to the number 1 spark plug cable adapter if it is operated by the high-tension circuit.

c. Turn on the ignition switch and crank the engine.

d. Note dwellmeter reading with the engine idling (500 RPM on the tachometer).

6. Check the ignition timing.

## APPENDIX B

## REFERENCE

| | | |
|---|---|---|
| TM 9-8000 | Principles of Automotive Vehicles | Jan 56 |

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ENLISTED MOS

CORRESPONDENCE/OJT COURSE

# ORDNANCE SUBCOURSE 63B203

## LESSON 8
## ELECTRICAL SYSTEMS

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

316

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# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

## LESSON ASSIGNMENT

Ordnance Subcourse 63B203 . . . . . . Wheeled Vehicle Electrical Systems

Lesson 8. . . . . . . . . . . . . . . . . . . Electrical Systems

Credit Hours . . . . . . . . . . . . . . . Four

Lesson Objective . . . . . . . . . . . . . After studying this lesson you will be able to:

1. Describe the construction of the wiring system.
2. Explain the purpose and operation of light switches.
3. Describe the construction and operation of the horn and horn switch.
4. Describe the construction and operation of instruments and gages.
5. Explain the circuit of the electric fuel pump and safety switch of an M151 1/4-ton truck.

6. Describe the procedures for troubleshooting electrical systems.

7. Describe the procedures for testing the horn circuit.

8. Describe the procedures for checking the fuel pump and safety switch of an M151 1/4-ton truck.

9. Describe the procedures for checking gages and sending units.

Study Assignment . . . . . . . . . . . . Study the text and illustrations carefully. They describe the inspection, testing, and maintenance of most of a vehicle's electrical system not previously covered in this subcourse.

Materials Required . . . . . . . . . . . All students: Exercise response list and answer sheet.
Correspondence/OJT option students: See appendix A.

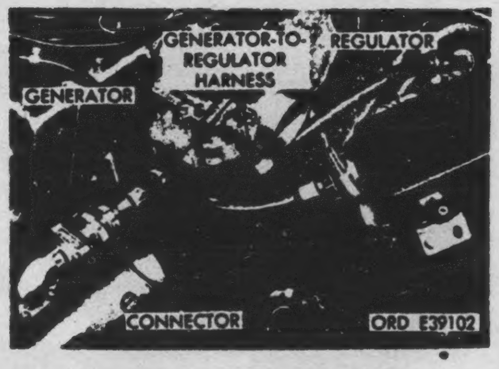
Suggestions . . . . . . . . . . . . . . . . Watch an experienced mechanic working on a vehicle's electrical system. Use the knowledge you obtained from the lessons to perform some tasks with the mechanic's help.

## STUDY TEXT

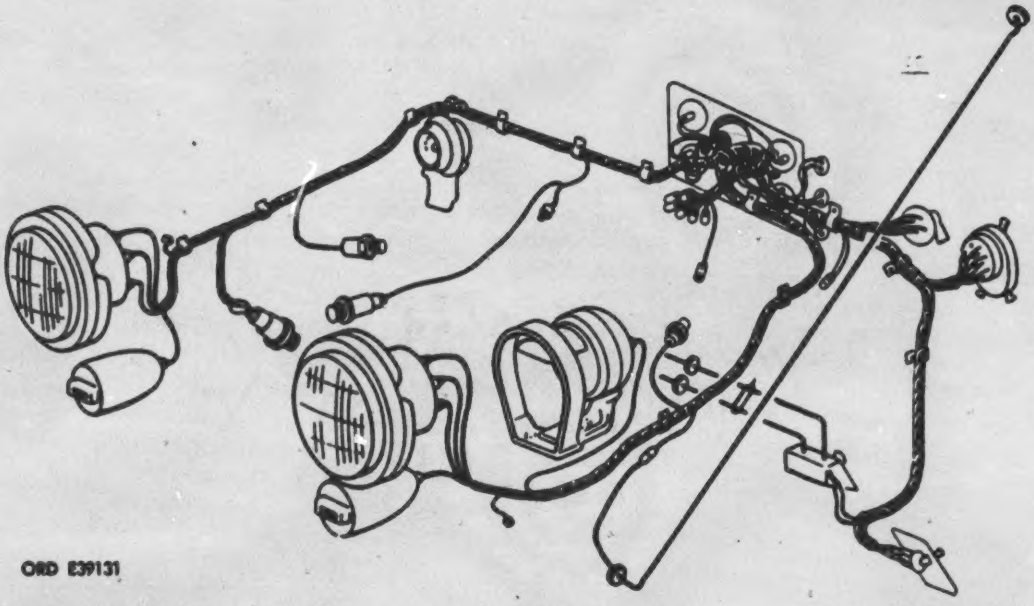
## SECTION I. WIRING SYSTEMS

1. **INTRODUCTION TO WIRING SYSTEMS.** In the previous lessons we covered several of the larger components of the electrical systems. They can and do cause trouble, but so do a lot of little things such as the wiring. To locate and correct the causes of electrical system troubles a considerable amount of skill and "know-how" is required. This lesson is designed to add to your "know-how" by explaining how the accessory systems operate. It also includes the steps to be followed in troubleshooting the accessory systems.

2. **WIRING SYSTEM CONSTRUCTION.** Many of the individual wires used to connect each electrical component or accessory to the batteries are assembled into a single conduit called a wiring harness.



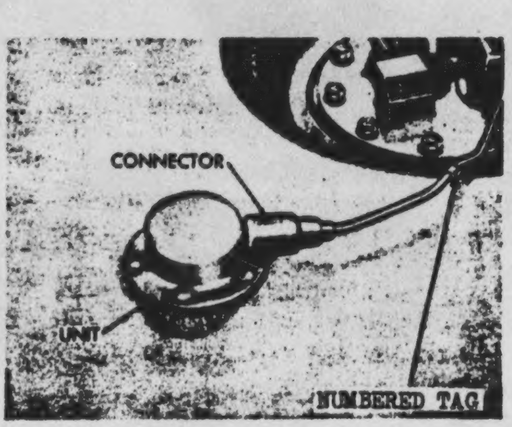
a. Notice how the individual wires in the harness branch off from the wiring harness to the components or accessories for which they supply the current.



ORD E39131

b. The wiring identification system used on all of the vehicles designed for the Army differs from the system used on civilian vehicles. Wires for individual circuits on civilian vehicles have different colored insulation around the wires. They may be solid colors, such as red, green, and blue, or they may be more than one color such as red with a yellow tracer or green with a black tracer.

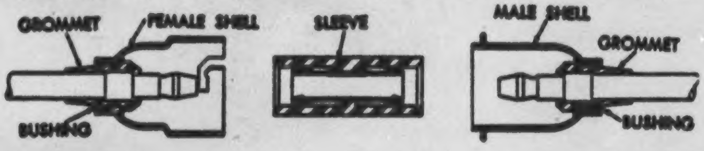
c. Military vehicles do not use a color code. Instead they use a number code. Each wire has a numbered metal tag near each end to identify the wire. The metal tag on the wire to the fuel gage sending unit is shown here.



d. Like circuits found on different types of vehicles will always have the same numbers. For example, the wire leading to the high beam side of the headlight is number 17 and the wire leading to the low beam side is number 18. Whether these headlight wires are on a 1/4-ton truck or a 60-ton tank, they will have the same numbers. Another example is the wire leading from the ignition switch to all of the electrical gages on the instrument panel. This wire is number 27 on all military vehicles.

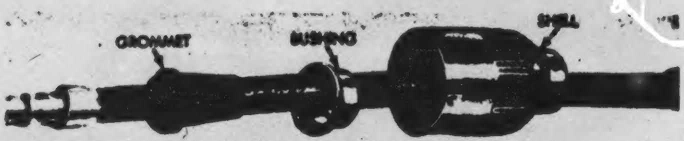
e. Another important difference between the wiring harness on military vehicles and the civilian ones is that the harness and individual wires on military vehicles have waterproof connections. Military vehicles have waterproof electrical systems because they must be capable of fording rivers or other bodies of water.

f. Illustrated in this figure are the bayonet types of waterproof connectors. These types of connectors are also called bell connectors because the two halves of the shell are bell shaped. Notice the sleeve in the center of the figure. The wires through the male and female shells are joined by the sleeve. The exposed terminals of the wires make electrical contact through the metal tube in the center of the sleeve. The outer part of the sleeve (illustrated with diagonal lines) is an insulator made of rubber or plastic.

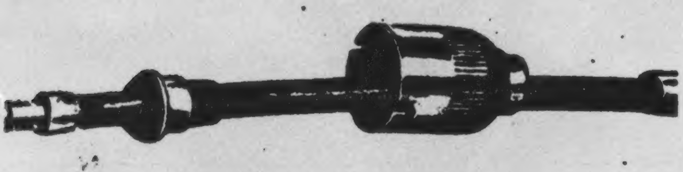


g. The narrow part of each shell contains a rubber grommet. When the male and female shells are locked together, the pressure of the bushing squeezes the grommet tightly around the wire, forming a waterproof connection.

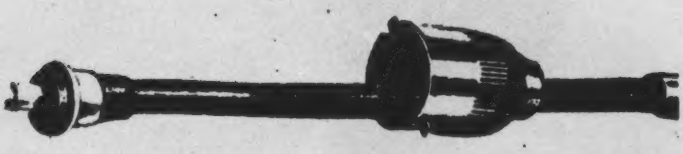
h. This figure illustrates the shell, bushing, and grommet more clearly. On some of the later model vehicles, such as the 1/4-ton truck, sockets and plugs are used instead of the bell connectors.



PARTS POSITIONED ON CABLE



BUSHING INSTALLED ON GROMMET



BUSHING AND GROMMET POSITIONED ON END OF CABLE

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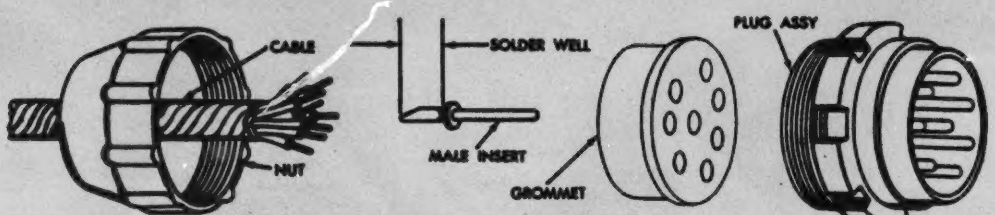
i. When it is necessary to join separate multiple wire harnesses together, waterproof male plugs and female receptacles are used. Notice the difference between the male inserts used with the plug in the A portion of the figure and the female inserts used with the receptacle in the B portion. Also, notice how the nuts fit over the grommets and thread on to the receptacle or plug. When the nuts are tightened, they squeeze the grommets around the wires, forming a watertight seal. Both A and B include instructions on the procedures to be followed to assemble the plug receptacle.



A

1—STRIP CABLE INSULATION EQUAL TO DEPTH OF SOLDER WELLS OF INSERTS.

2—REMOVE GROMMET RETAINING NUT FROM PLUG ASSEMBLY AND SLIDE BACK OVER CABLE.

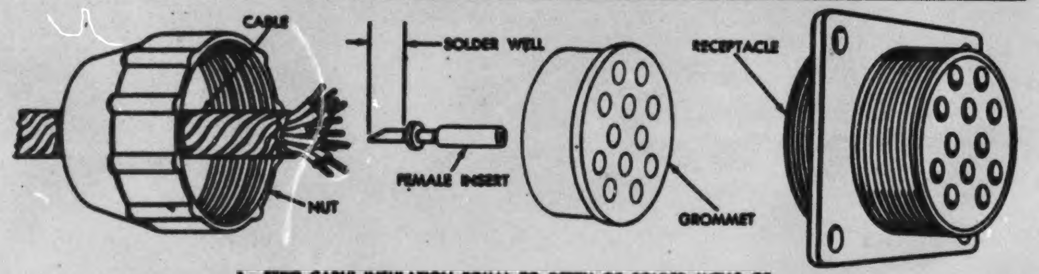
3—SLIDE GROMMET BACK FROM PLUG ASSEMBLY AND REMOVE DAMAGED CABLE.

4—PASS REPLACEMENT CABLE THROUGH GROMMET RETAINING NUT AND GROMMET, INSERT INTO SOLDER WELLS OF INSERTS, AND SOLDER.*

5—SLIDE GROMMET OVER INSERTS AND PRESS INTO PLUG ASSEMBLY UNTIL SEATED.

6—THREAD GROMMET RETAINING NUT TO PLUG ASSEMBLY.

MALE-TYPE PLUG ASSEMBLY (WITH SPANNER COUPLING NUT).



B

1—STRIP CABLE INSULATION EQUAL TO DEPTH OF SOLDER WELLS OF INSERTS.

2—REMOVE GROMMET RETAINING NUT FROM PLUG ASSEMBLY AND SLIDE BACK OVER CABLE.

3—SLIDE GROMMET BACK FROM RECEPTACLE ASSEMBLY AND REMOVE DAMAGED CABLE.

4—PASS REPLACEMENT CABLE ENDS THROUGH GROMMET RETAINING NUT AND GROMMET, INSERT INTO SOLDER WELLS OF INSERTS, AND SOLDER.*

5—SLIDE GROMMET OVER INSERTS AND PRESS INTO RECEPTACLE ASSEMBLY UNTIL SEATED.

6—THREAD GROMMET RETAINING NUT TO RECEPTACLE ASSEMBLY.

*NOTE, CONTACT SIZES 8, 4, AND 0 MAY BE REMOVED FROM CONNECTOR TO SIMPLIFY REPAIR.

FEMALE-TYPE RECEPTACLE ASSEMBLY

j. The grommets for both the plug and receptacle are lettered instead of numbered. Which numbered wire goes in which lettered hole in the grommet is illustrated in the vehicle technical manuals.

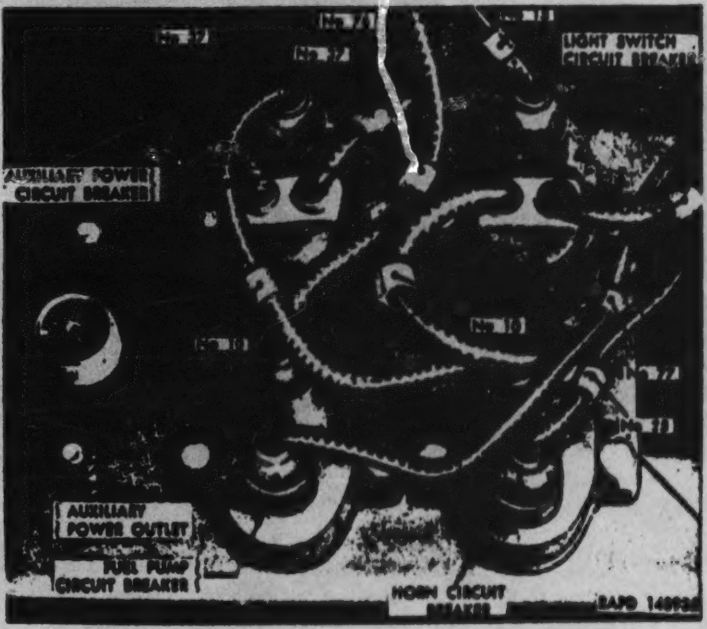
k. In order to trace troubles through wiring harnesses, it is necessary to have a vehicle wiring circuit diagram. Such a diagram is often called a schematic.

l. Figure A of foldout 1, in the back of the lesson, is a wiring diagram of the 1/4-ton truck, M151. Notice the numbers on the wires. The names of each of the numbered circuits are listed in figure B of the foldout.

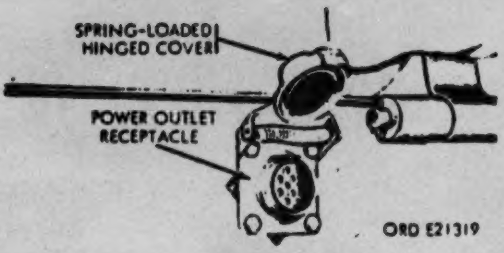
m. In figure A notice how the numbered wires fit in the lettered connector. Before going further in this lesson, practice tracing a few of these wires. Take wire number 17 at the headlight and trace it back through the dimmer switch to the light switch in the cab of the truck. Notice especially the lettered receptacles it passes through at the light switch. From the light switch trace the circuit back to the batteries.

n. Three circuit breakers are shown just below the batteries and starter motor in figure A of the foldout. Circuit breakers do the same thing as fuses in other electrical circuits. They protect the circuits from overload. Unlike fuses, however, which have to be replaced if they blow (burn) out, the circuit breakers used on military vehicles are automatic reset types. As soon as a circuit breaker opens the circuit it starts to cool off. After it is cool enough, it closes the circuit again. It will continue to do this until the repairman corrects the cause of the overloaded circuit.

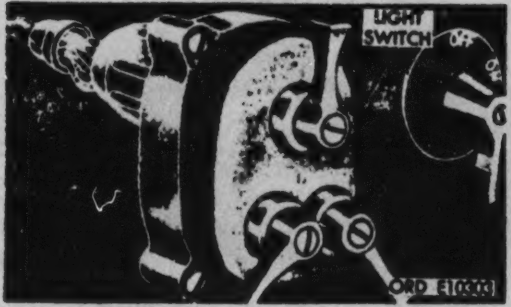
o. A group of circuit breakers installed in a 2-1/2-ton truck are illustrated here. On some models of trucks the circuit breakers are mounted on the firewall (the metal partition between the cab and the engine compartment). On other models they may be located under the dash or behind the instrument panel.


No 12
LIGHT SWITCH CIRCUIT BREAKER
AUXILIARY POWER CIRCUIT BREAKER
No 10
AUXILIARY POWER OUTLET
FUEL PUMP CIRCUIT BREAKER
HORN CIRCUIT BREAKER

p. On the lower right side of figure A, foldout 1, a lettered trailer receptacle is illustrated. When the truck on which such a receptacle is mounted pulls a trailer, the trailer cable is plugged into this receptacle.. The light switches on the truck then control the lights on the trailer.



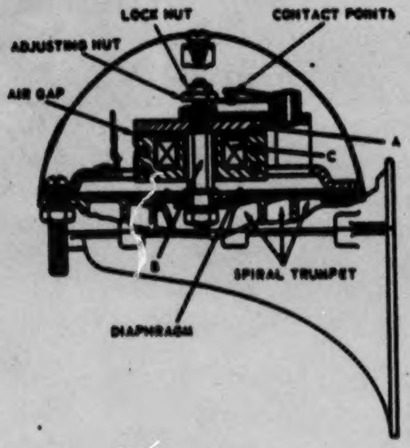
3. PURPOSE AND OPERATION OF LIGHT SWITCHES. All of the lights on the vehicle are controlled by one or more of three light switches. The blackout (BO) marker, BO drive, service taillight, and instrument panel lights are controlled entirely by the main light switch. The service headlights and the high beam indicator light are controlled by the main light switch and the dimmer switch. The main light switch and the stoplight switch control the blackout, stoplight, and the service stoplights.



a. Take a close look at the markings on the light switch in foldout 2. It shows the possible positions of the main light switch and which lights will burn in each position. The selector lever can be moved to the BO marker position without moving the unlock lever. In order to move the selector lever to any other position, the unlock lever must be moved in the direction shown by the arrow. All possible positions of the main light switch levers are shown in foldout 2. The lights that burn with the lever in each position are also illustrated. The notes at the bottom of the foldout further explain the switch positions and the lights.

b. Anytime the service or blackout taillight and stoplights are on, the circuit is also completed to the trailer receptacle (A of foldout 1). Notice that some of the wires to the trailer receptacle are numbered the same as those connected to the service, blackout, and stoplights. If a trailer is connected to the truck, its lights will then be controlled by the truck's light switches.

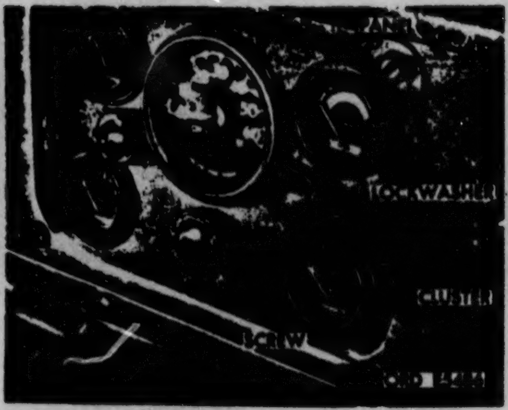
c. In addition to the lights and switches already described, some military vehicles are equipped with parking lights and directional turn signal lights. Parking lights are controlled by the main light switch. An additional switch is required for the turn signal lights. It is mounted on the steering shaft column below the steering wheel and is controlled by a lever.



**4. CONSTRUCTION AND OPERATION OF HORNS AND HORN SWITCHES.** Most military vehicles use a vibrator-type horn. A cross sectional view of a typical horn is shown here. When the horn switch (which is usually the horn button on the steering wheel) is closed, current flows through contact points in the horn and then through the coil of an electromagnet. With the coil energized, washer "A" and bolt "B" are pulled down. As they move downward they carry the adjusting nut and diaphragm with them. The downward movement of the adjusting nut opens the contact points, breaking the circuit through the coil. Now the coil is no longer an electromagnet and the spring action of the diaphragm returns the diaphragm, washer "A," bolt "B," and the points back to their original position. With the points again closed the coil is energized and the whole process is repeated. These events take place very rapidly. The metal diaphragm in fact vibrates because of the rapid back and forth movement. The vibrating diaphragm produces the sound which is transmitted through the trumpet to the surrounding air and to the ears of anyone close by.

a. The sound made by the horn can be changed by increasing or decreasing the airgap between the adjusting nut on bolt "B" and the contact points. However, horns seldom get out of adjustment. Usually, if the horn does not blow or if it produces an unnatural sound, the trouble is in the horn wiring circuit or the batteries.

b. Now look at the wiring diagram in figure A of foldout 1. Trace the horn circuit from the horn switch through the horn to the battery. Remember, what is referred to on the wiring diagram as the horn switch is commonly called the horn button and is located on the steering wheel.



**5. CONSTRUCTION AND OPERATION OF INSTRUMENTS AND GAGES.** The instruments and gages used on military wheeled vehicles are grouped together in an instrument cluster that is bolted to the dash panel. The entire cluster can be pulled away from the dash panel by turning each of the four cluster mounting screws counterclockwise (to the left) one-quarter turn.

a. The following items are included in the instrument panels of all military wheeled vehicles:

(1) Speedometer.

(2) Fuel gage.

(3) Battery-generator indicator.

(4) Oil pressure gage.

(5) Temperature gage.

(6) High beam indicator light.

(7) Instrument panel lights.

b. In addition to the items listed above, the instrument clusters used on vehicles with air or air over hydraulic brakes will have an air pressure gage. Some wheeled vehicle instrument clusters also include tachometers.

c. To the greatest possible extent the gages, speedometer, and instrument panel lights are standardized. That is, they are interchangeable from one military vehicle to another. For example, the speedometer on the 1/4-ton truck can be used on a 60-ton tank.

d. The battery-generator indicator and the fuel level gage are also identical on all tactical vehicles. The temperature gage on the 1/4-ton truck will work on any other military truck with a liquid-cooling system. The oil pressure gage can also be used on other vehicles provided the oil pressures developed are within the range of the gage on the 1/4-ton truck. This high degree of interchangeability between the gages and instruments used on military vehicles greatly simplifies the repair parts supply problem, because there is no need to stock a large variety of instruments and gages.

e. All of the electrical gages in the instrument clusters on military vehicles are the two-coil-type except the battery-generator indicator. The operating principles of both types must be understood by the repairman in order to locate and correct troubles in the gages or gage circuits.

Note. - Refer to foldout 3 during the discussion on the fuel gage.

f. Foldout 3 illustrates a two-coil-type fuel gage and the entire fuel gage circuit. When the ignition switch is closed, current from the battery flows from ground through the operating coil of the gage on the instrument panel.

(1) After flowing through the operating coil the current reaches a terminal in the bottom of the gage. Here it joins with current from the sending unit (also known as the transmitting unit). Then on through the limiting coil.

(2) Remember, electricity will take the easiest path. If it is easier for current to flow through the operating coil than through the sending unit, that is the way most of it will go. If the current meets less resistance through the sending unit, most of it will flow that way.

(3) Now study the sending unit illustrated in the foldout. It consists of a resistance unit called a rheostat and a grounded contact arm. The contact arm is moved back and forth across the resistance unit by the float. The position of the float is determined by the level of the fuel in the tank.

(4) In the empty position the float is down and the contact arm contacts the resistance unit at the extreme left side of the unit. Current can then flow from ground through the contact arm, and then through the wire to the terminal in the gage. This is an easy path because the current does not have to go through the rheostat in the sending unit.

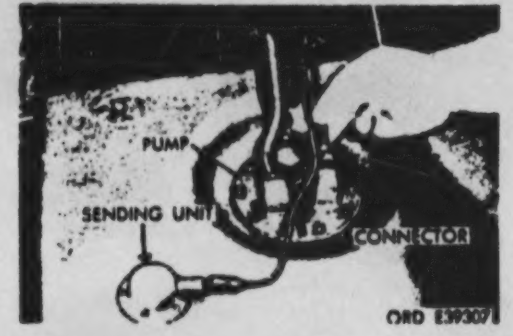
(5) With most of the current flowing through the sending unit, very little will flow through the operating coil in the gage. Under these conditions the magnetic field around the operating coil will be too weak to pull the gage needle (pointer) to the right. The gage will read empty (E on the gage in the foldout).

(6) On the other hand, with fuel in the tank the float rises and moves the rheostat contact arm in the sending unit to the right (dotted line in the foldout). The current flow through the sending unit is reduced because now

it must travel through part of the rheostat. Reduced current flow through the sending unit means increased current flow through the operating coil. The increased current flow will also increase the strength of the magnetic field around the operating coil. The operating coil's magnetic field will pull the gage needle to the right.

(7) When the fuel tank is full, practically all of the current will flow through the operating coil. Then the strong magnetic field around the operating coil will pull the gage needle all the way to the right (to the F mark on the gage).

(8) The actual fuel tank sending unit used on the 1/4-ton truck, M151, is illustrated in this figure.



g. The oil pressure and engine temperature gages on the instrument panel are, like the fuel gage, coil-type gages; however, their sending or transmitting units are different. The resistance in the oil pressure sending unit varies with the pressure on the engine oil. The resistance in the water temperature sending unit varies with the temperature of the water around its metal bulb. As you will see later in this lesson, the methods of checking the oil pressure and temperature sending units are different from that used to check the fuel gage sending unit. However, the procedures for checking all three gages on the instrument cluster are the same.

h. The water temperature sending unit is located in the rear of the cylinder head on the 1/4-ton truck. The oil pressure gage is threaded into the oil filter adapter on the right side of the engine below the distributor.

DISTRIBUTOR
SENDING UNIT CONNECTOR
DISTRIBUTOR CONNECTOR
ORD E38963

i. The battery-generator indicator is really a voltmeter. However, instead of having a numbered scale like the voltmeter in your LVCT, it has a color coded scale. Current to operate the indicator flows through one of the number 27 wires whenever the ignition switch is closed. The left side of the scale on the face of the battery-generator indicator is red, the center portion of the scale is amber or yellow, and the right side of the scale is green.

(1) If the batteries in the vehicle are in good condition, the battery-generator indicator needle should move to the right when the ignition switch is in the "on" position. The needle should move well into the yellow part of the scale. In fact, it should move close to the green section of the scale. While cranking the engine the needle may move back slightly toward the red section of the scale.

(2) After the engine is started and the generator has fully recharged the battery, the needle should move into the green section of the scale. If it does not, the generator charging voltage is probably too low.

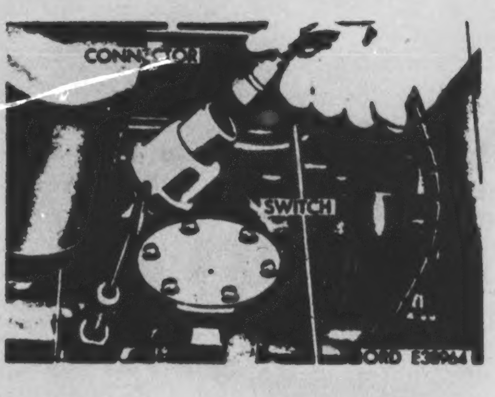
(3) If, of course, the needle stays in the red portion of the indicator when the switch is turned on, the batteries are probably discharged or dead.

(4) Notice in the A portion of foldout 1 that the battery-generator indicator is grounded to the instrument cluster. Anytime you pull the instrument cluster away from the dash panel, use a jumper wire. Clip one end of the jumper to the cluster and the other end to the panel so the ground circuit is complete. Failure to ground the cluster may damage all of the gages.

6. **OPERATION OF THE ELECTRIC FUEL PUMP AND SAFETY SWITCH CIRCUIT.** The fuel pump used on the 1/4-ton truck, M151, is an electrically operated plunger type. It is mounted inside the fuel tank. The figure illustrates the pump and the fuel filter that completely surrounds it. Current to operate the pump is supplied through circuit number 77 (figure A of foldout 1).

PUMP
GASKET
ORD E5374

a. The current to operate the pump is usually controlled through the ignition switch. Notice we say "usually controlled." For safety reasons another switch called the oil pressure switch or safety switch is also in the circuit.



b. To understand the need for the safety switch, let's suppose that current for the fuel pump was controlled only by the ignition switch. Let's suppose further that someone accidently left the switch on overnight. At the very least such an act would discharge the batteries. In addition, it is likely that the pump would force more fuel into the carburetor causing it and the engine to become flooded with gasoline.

c. To prevent the operation of the pump when the engine is not running or when the engine oil pressure is dangerously low, the safety switch is placed in the circuit.

d. Now examine the entire fuel pump circuit in foldout 1. Start with wire number 12 at the ignition switch. Follow this wire to the point where wire number 76 is connected to it. Wire 76 goes to the fuel pump circuit breaker. From the circuit breaker wire 77A, go to the safety switch (called the "switch assembly, oil pressure" on the diagram). From the safety switch follow wire number 77 to the fuel pump.

e. Notice in the diagram that the switch between wires 77 and 77A is open. No current will flow through the pump to these wires until the switch is closed. The switch is closed by engine oil pressure. Unless the engine is running there is no oil pressure, so leaving the ignition switch on with the engine stopped will not cause the fuel pump to operate.

f. Now let's suppose this vehicle runs out of gas. After filling the tank we try to start the engine. At cranking speed the engine oil pressure is too low to close the switch between wires 77 and 77A. This means we have no circuit to the pump, and, therefore, no gas to the carburetor.

g. In order to provide current to the pump when the engine is being cranked, wire number 77B between the starter motor and the safety switch is used. Notice that wire 77B and cable 6 are connected to the terminal on the starter motor. Anytime the starter is turning, current is flowing through cable 6. Since it is connected to the same terminal as wire 77B, part of the current will move through 77B to the safety switch. When the engine is not running, the switch between 77 and 77B is closed. In this manner, current is supplied to the fuel pump during the operation of the starter motor. After the engine is cranked, the safety switch is opened between wires 77 and 77B and is closed between wires 77 and 77A.

Note. - Complete exercises number 131 through 147 before continuing to section II.

131. Groups of insulated wires assembled together are called a wiring

a. conduit.
b. harness.
c. cable.

132. How does the Army system of wire identification differ from the civilian identification system?

a. The Army uses numbers and the civilian system uses colors
b. The Army uses colors and the civilian system uses numbers
c. The Army uses letters and the civilian system uses numbers

133. What is used with each bell connector to make a waterproof seal on wire terminals?

a. Plugs
b. Grommets
c. Sliprings

134. The openings in the multiple wire receptacles used on military vehicles are identified by

a. colors.
b. numbers.
c. letters.

135. What produces the sound in the horn assembly used on the M151 truck?

a. Vibrating diaphragm
b. Magnetic field
c. Trumpet assembly

136. The purpose of a circuit breaker is to

    a. control battery voltage.
    b. protect the circuit against overload.
    c. maintain a constant voltage in the circuit.

137. All current for the lighting system on an M151 truck is controlled by the

    a. ignition switch.
    b. main light switch.
    c. dimmer switch.

138. Military vehicles with airbrakes will have an air

    a. pressure gage.
    b. temperature gage.
    c. volume gage.

139. What determines the position of the contact arm in the sending unit of the fuel gage?

    a. Float
    b. Rheostat
    c. Operating coil

140. All of the electrical gages used on the M151 1/4-ton truck are of the two-coil type except the

    a. oil pressure gage.
    b. battery-generator indicator.
    c. temperature gage.

141. When the fuel gage reads full (F) most of the current is flowing through the

    a. operating coil.
    b. rheostat.
    c. contact arm.

142. What type of meter is the battery-generator indicator?

   a. Ohmmeter
   b. Voltmeter
   c. Ammeter

143. The battery-generator indicator is grounded to the vehicle's

   a. body.
   b. instrument cluster.
   c. dash panel.

144. The fuel pump used on the M151 truck is mounted

   a. on the engine.
   b. under the dash panel.
   c. in the gas tank.

145. The purpose of the oil pressure switch on the M151 truck is to

   a. stop the operation of the fuel pump when the oil pressure is low.
   b. prevent the batteries from discharging through the oil pressure gage.
   c. limit the amount of current delivered to the oil pressure sending unit.

146. Without moving the unlock lever, the selector lever on the main light switch can be moved to the

   a. service stoplight position.
   b. blackout drive position.
   c. blackout marker position.

147. On the M151 truck, what should the input voltage at the fuel pump be if the ignition switch is on, the engine is not running, and the starter motor is not turning?

   a. 0 volt
   b. 1.5 volts
   c. 24 volts

## SECTION II. MAINTENANCE OF ELECTRICAL SYSTEMS

7. TROUBLESHOOTING AND MAINTENANCE OF ELECTRICAL SYSTEMS. Before studying the procedures for troubleshooting the electrical system, review lesson 63B203-3 on the use of electrical test equipment. Especially review the portion of the lesson that pertains to the voltmeter of the LVCT and the DC voltmeter and ohmmeter on the multimeter.

a. In all cases where replacement of lights, gages, or switches is indicated, refer to the vehicle technical manual for procedures to be followed in replacing and adjusting components.

b. Always begin electrical system checks by testing the voltage of the batteries. Weak batteries affect all of the circuits.

c. Electrical test equipment is an absolute "must" when troubleshooting electrical systems. Remember, however, that test equipment is worthless in the hands of a repairman who does not know how to use it, or how to interpret the readings obtained. Also remember that good judgment, or plain old commonsense, is just as important as test equipment when troubleshooting electrical systems.

d. In the exercise of good judgment, before you start troubleshooting, ask yourself such questions as:

(1) What is the trouble?

(2) What are the things that could cause the trouble?

(3) Where should I start testing? Why?

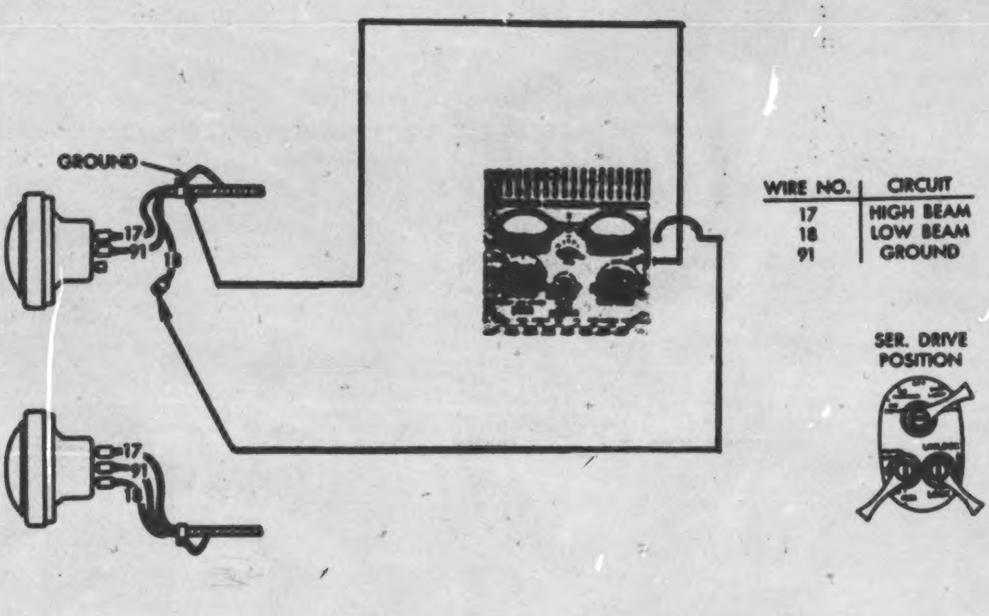
(4) How should I test to locate the trouble?

(5) What should I find if the circuit is good? Bad?

(6) What test equipment will best do the job?

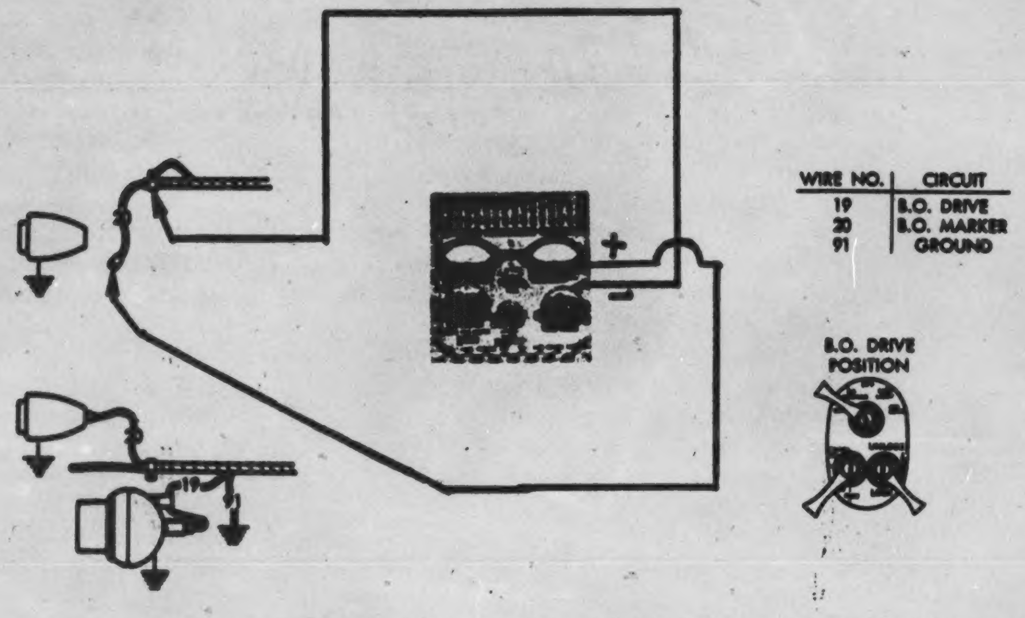
e. Let's suppose the right headlight low beam does not light but the left one does.. Should you start checking at the main light switch? No! Why? Because current for both lights is certainly flowing through the main light switch from the dimmer switch through wire number 16. Otherwise neither headlight would burn. The dimmer switch is also working because current is flowing through it from the left headlight. The trouble, therefore, has got to be somewhere between the junction of the number 18 wires at the dimmer switch and ground at number 91 wire at the right headlight (figure A of foldout 1).

(1) The place to start checking would be at the connector at the right headlight where wire number 18 from the dimmer switch connects to wire number 18 in the headlight. This figure illustrates the proper use of the voltmeter to test the circuit between the low beam headlight wire number 18 and the dimmer switch. With the left headlight burning as in our example, the voltmeter should read battery voltage (in this case 24 volts). If it does, the trouble is between number 18 wire into the headlight and number 91 wire to ground. If it reads zero volts, there is an open circuit (wire broken or cut in two) between the checkpoint and the junction with wire number 18 going to the left headlight.

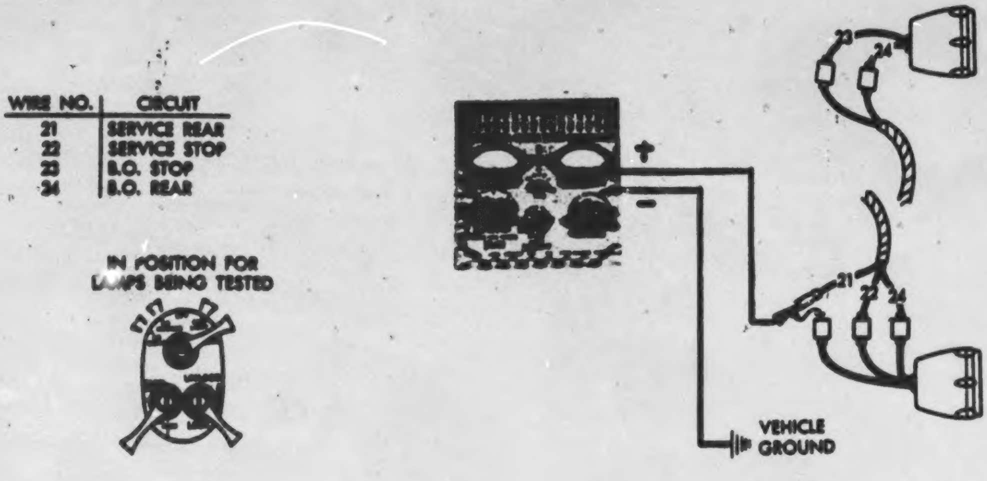


(2) In actual practice, when checking any light circuit, it is usually better to start at the connectors closest to the light bulb. The reason for starting the circuit test at these connectors is that they are the easiest to get to, and tests at these points can be performed more quickly.

f. This figure illustrates a wiring circuit test being performed at the right front blackout markers. On this and all other light circuit tests the voltmeter switch is in the 50-volt position.

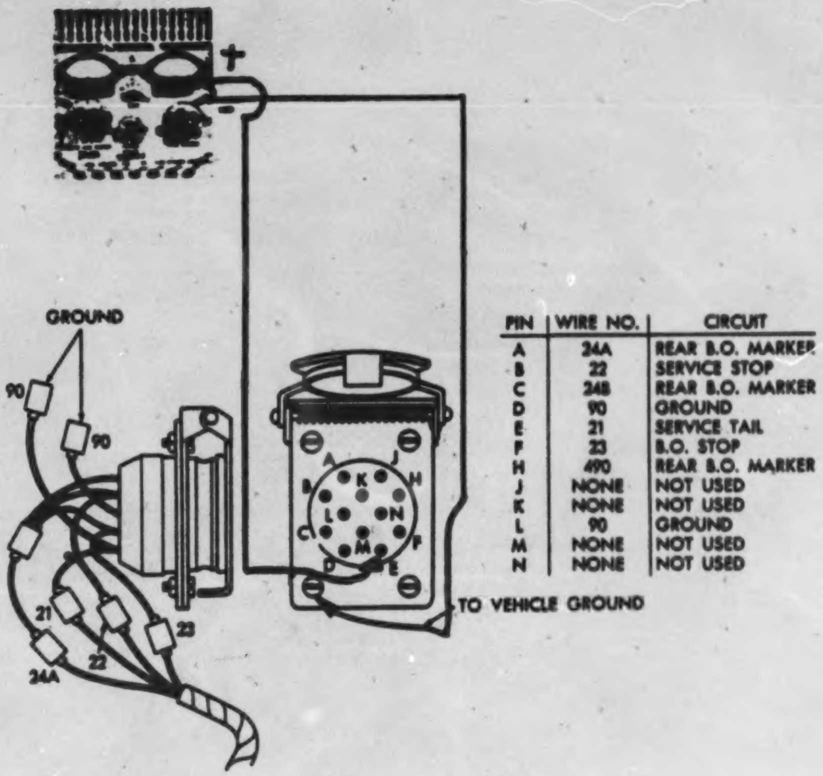

+
−
19
91
WIRE NO. | CIRCUIT
19 | B.O. DRIVE
20 | B.O. MARKER
91 | GROUND
B.O. DRIVE POSITION

g. This figure illustrates the same test at the service taillight feed wire. Notice the positions of the selector lever on the main light switch when performing these tests. The lever must be in the positions shown. Otherwise you will get a reading of zero on the voltmeter.


WIRE NO. | CIRCUIT
21 | SERVICE REAR
22 | SERVICE STOP
23 | B.O. STOP
24 | B.O. REAR
IN POSITION FOR LAMPS BEING TESTED
+
−
23
24
21
22
24
VEHICLE GROUND

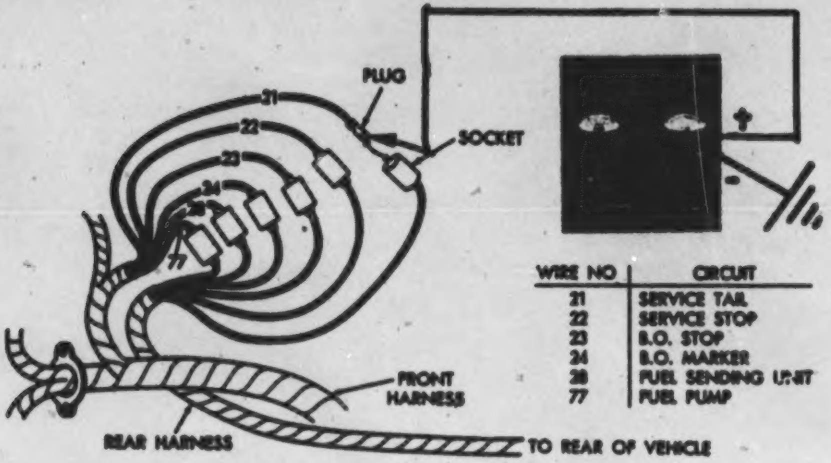
(1) Now let's suppose we perform the rear lamp connector voltage test and the voltmeter reads zero when connected to wire number 21. With the main light in the "SER DRIVE" position, the headlights should be burning. If they are, we know current is flowing through the main light switch so the trouble cannot be the battery light circuit breaker or wire number 15 from the main light switch. The trouble, therefore, is between the service taillight contact in the main light switch and the terminal of wire number 21.

(2) We can doublecheck the zero reading we got at wire number 21 by connecting the voltmeter into the terminal lettered "E" in the figure. Notice the circuit identification chart shows that wire number 21 also feeds terminal "E" in the trailer receptacle. If the voltmeter still reads zero when connected as shown in the figure, we can be doubly sure there is no current flowing through wire number 21.



| PIN | WIRE NO. | CIRCUIT |
|---|---|---|
| A | 24A | REAR B.O. MARKER |
| B | 22 | SERVICE STOP |
| C | 24B | REAR B.O. MARKER |
| D | 90 | GROUND |
| E | 21 | SERVICE TAIL |
| F | 23 | B.O. STOP |
| H | 490 | REAR B.O. MARKER |
| J | NONE | NOT USED |
| K | NONE | NOT USED |
| L | 90 | GROUND |
| M | NONE | NOT USED |
| N | NONE | NOT USED |

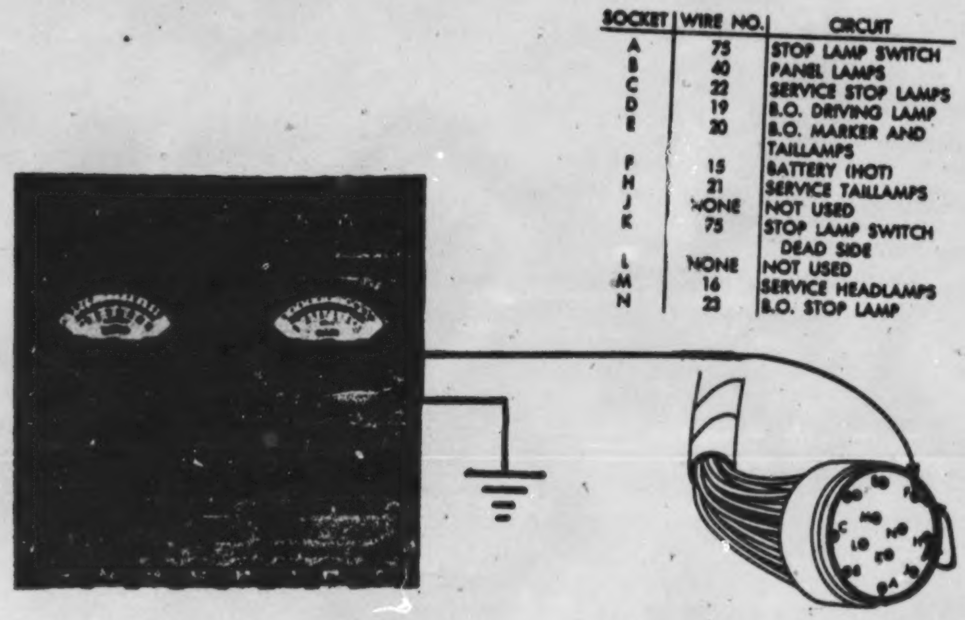
(3) The next step to take in locating the trouble is to go to the point where the rear wiring harness (which includes wire number 21) connects to the harness from the main light switch. The point where these two harnesses connect is under the dash panel of the truck. Locate the wire number 21 under the dash and disconnect it. Connect the voltmeter as shown in this figure. With the light switch lever still in the extreme right-hand position, the meter should read battery voltage (approximately 24 volts). If it does, start checking the rear harness inch by inch, looking for a break (open circuit) in wire number 21. If no break is evident, replace the entire rear harness. If the break is found, you can splice it in order to make a complete circuit to the service taillight and trailer receptacle.



| WIRE NO | CIRCUIT |
|---|---|
| 21 | SERVICE TAIL |
| 22 | SERVICE STOP |
| 23 | B.O. STOP |
| 24 | B.O. MARKER |
| 28 | FUEL SENDING UNIT |
| 77 | FUEL PUMP |

(4). On the other hand, if a zero reading is obtained when performing this test, disconnect the large connector at the rear of the main light switch. Leave the voltmeter connected as in the previous test.

(5) Now study the figure which illustrates the lettered receptacle you disconnected from the light switch. Notice the wiring chart next to the receptacle. Wire number 15, which is the "hot" wire to the battery, connects to the socket lettered "F" and wire number 21 connects to the "H" socket. Using a short jumper wire, as illustrated, connect socket "F" to socket "H."



| SOCKET | WIRE NO. | CIRCUIT |
|---|---|---|
| A | 75 | STOP LAMP SWITCH |
| B | 40 | PANEL LAMPS |
| C | 22 | SERVICE STOP LAMPS |
| D | 19 | B.O. DRIVING LAMP |
| E | 20 | B.O. MARKER AND TAILLAMPS |
| F | 15 | BATTERY (HOT) |
| H | 21 | SERVICE TAILLAMPS |
| J | NONE | NOT USED |
| K | 75 | STOP LAMP SWITCH DEAD SIDE |
| L | NONE | NOT USED |
| M | 16 | SERVICE HEADLAMPS |
| N | 23 | B.O. STOP LAMP |

LIGHTING SWITCH CONNECTOR VOLTAGE TEST

CONNECT JUMPER FROM "F" TO FAULTY CIRCUIT

(6) If the voltmeter at the other end of wire 21 now reads battery voltage, wire 21 from the light switch connector to the rear harness is OK. To doublecheck this connect the number 21 wires from the front and rear harnesses together and see if the service taillight burns. If it burns now, there is nothing wrong with the circuit from the light switch to the service taillight.

(7) So what is the trouble? The main light switch itself. We have proved the circuit is OK by tracing it all the way back to the switch. The remedy is to replace the light switch.

h. Any of the light circuits can be tested in a similar manner. Notice we used the voltmeter for all of the tests. Never use the ammeter for such tests because it is a low-resistance meter and would allow too much current to flow. Using an ammeter the way we used the voltmeter would, at the very least, pop the circuit breaker and could cause the wires to overheat and melt.

8. **TESTING THE HORN CIRCUIT.** If the horn fails to blow when the switch on the steering wheel is closed, disconnect both wires at the horn. Ground the negative voltmeter lead and touch the positive lead to one of the wires disconnected from the horn. Notice both of the wires are numbered 25 (foldout 1).

a. If the voltmeter reads zero when touched to the first wire, touch the positive voltmeter lead to the other wire. One of the wires should read 24 volts and the other should read zero.

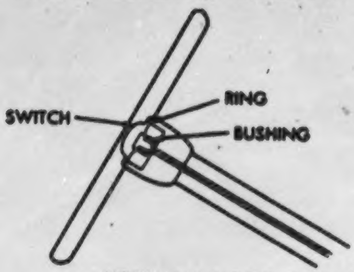
(1) Let's suppose one wire reads 24 volts and the other one zero volts. Connect the live wire (the one that showed 24 volts back to the horn). Now touch the positive voltmeter lead to the other number 25 terminal on the horn. (Be sure the negative voltmeter lead is still connected to a good ground.) If the voltmeter still reads zero, replace the horn. If it reads 24 volts, check the circuit back to the horn switch.

(2) Connect the second number 25 wire back to the horn. Then disconnect the number 25 wire at the bottom of the steering gear. Connect the positive voltmeter lead to the wire from the horn and the negative lead to ground. The voltmeter should read 24 volts. If it reads zero, there is an open circuit between that point and wire number 25 back at the horn. Inspect the wiring harness that connects wire number 25 for cuts or breaks. Repair or replace the wire.

(3) Before replacing the wire if no breaks are evident, closely examine the terminals at the ends of the wires. Sometimes they are loose on the wires or corroded and not making electrical contact. Always be sure the terminals and connectors are good on any wires before deciding there is an open circuit.

(4) Let's suppose the voltmeter had a reading of 24 volts when connected to the number 25 wire at the bottom of the steering column. We can doublecheck at this point by using a jumper wire. Clip one end of the jumper to the frame of the vehicle and the other end to wire number 25 coming from the horn. With the jumper wire connected in this fashion, the horn should blow.

(5) If the horn blows, connect the number 25 wire at the bottom of the steering gear to the number 25 wire going into the steering gear and up to the horn button on the steering wheel (remember the horn button is called the switch). Remove the horn button from the steering wheel. Ground the horn button using

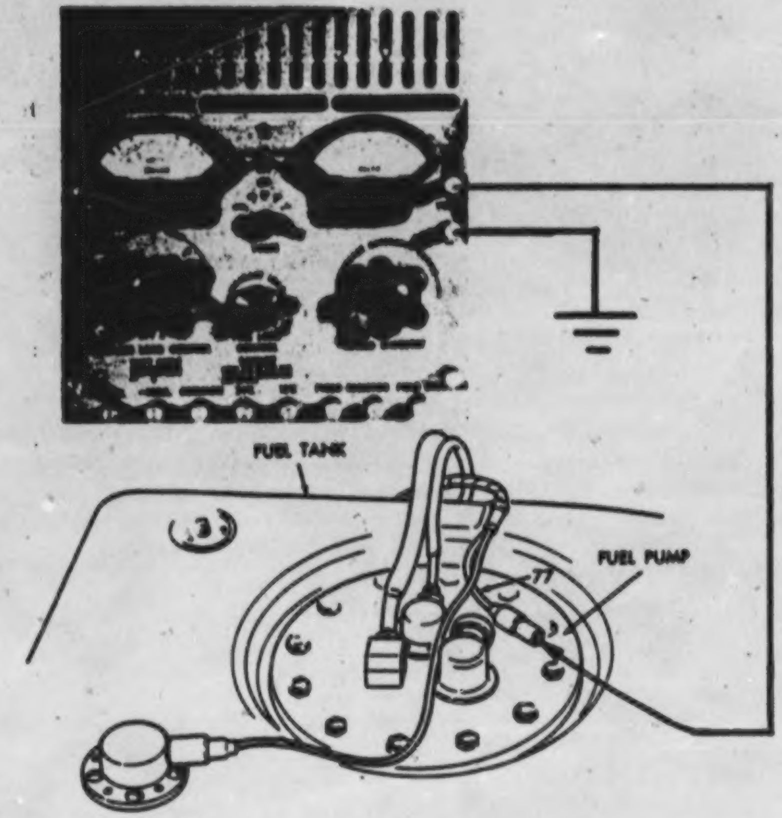


HORN INOPERATIVE CHECK

a jumper wire. If the horn does not blow, pull the number 25 wire up and out of the steering column shaft. If the wire, terminals, and horn button contacts are OK, check the bushing in the steering column. Replace the bushing if it is worn because it is the ground side when the horn switch is closed.

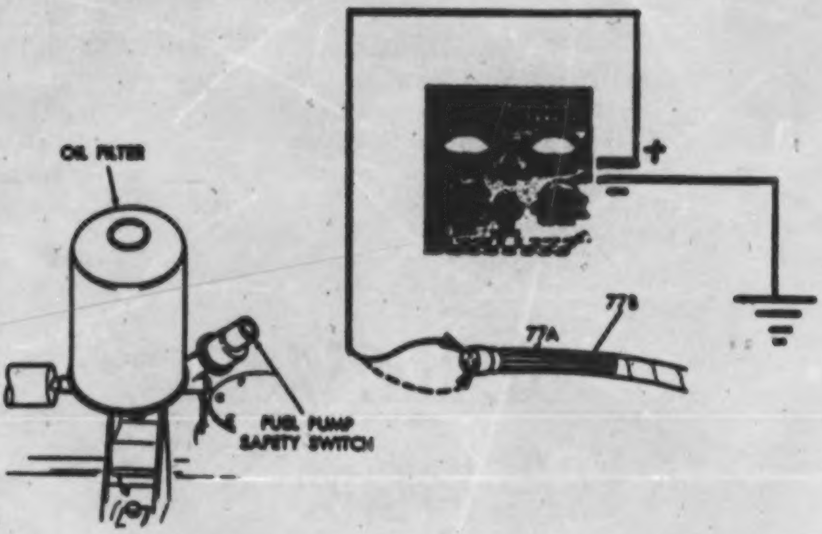
b. In the initial test at the horn, if a voltage reading of zero is obtained in the number 25 wire from the circuit breaker, trace that circuit back to its source in the same manner the light wires were traced back to their source.

9. CHECKING THE FUEL PUMP AND SAFETY SWITCH. To check the fuel pump circuit, connect the voltmeter positive lead to the number 77 wire at the fuel pump and the negative lead to ground. With the engine running or with the starter turning, the voltmeter should read close to 24 volts. The voltage may be less than 24 when the starter is turning the engine. The voltage should be zero if the engine is not running or if the starter is not operating.



FUEL PUMP VOLTAGE TEST

a. If no voltage reading is obtained at the pump, disconnect the wiring harness from the safety switch on the engine. Connect the voltmeter to wire 77A. Turn on the ignition switch. The voltmeter should indicate 24 volts. Now move the positive voltmeter lead to wire 77B. With the ignition switch in the off position, close the starter switch. The voltmeter should read 24 volts or slightly less.

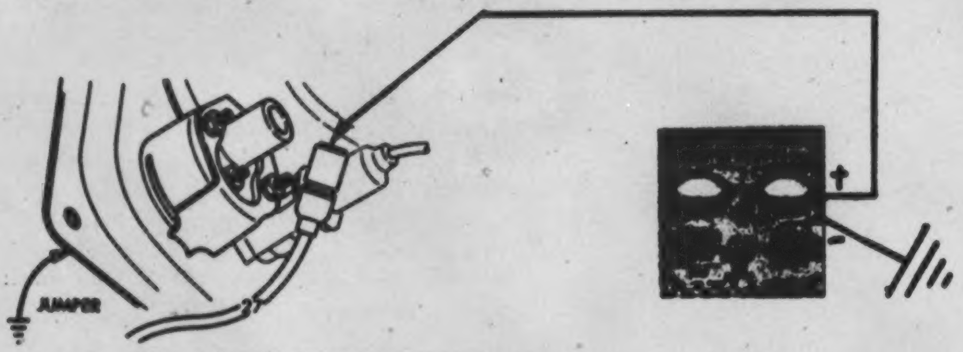


FUEL PUMP SAFETY (OIL PRESSURE) SWITCH TEST

b. If correct voltage readings are obtained at wires 77A and 77B, but the reading was zero at wire 77 when the engine was running or the starter was operating, replace the safety switch. Then repeat the test at the fuel pump. If the correct voltage readings are obtained at wire 77 at the fuel pump, but the pump does not operate, replace the pump. (When the pump is operating it can usually be heard.)

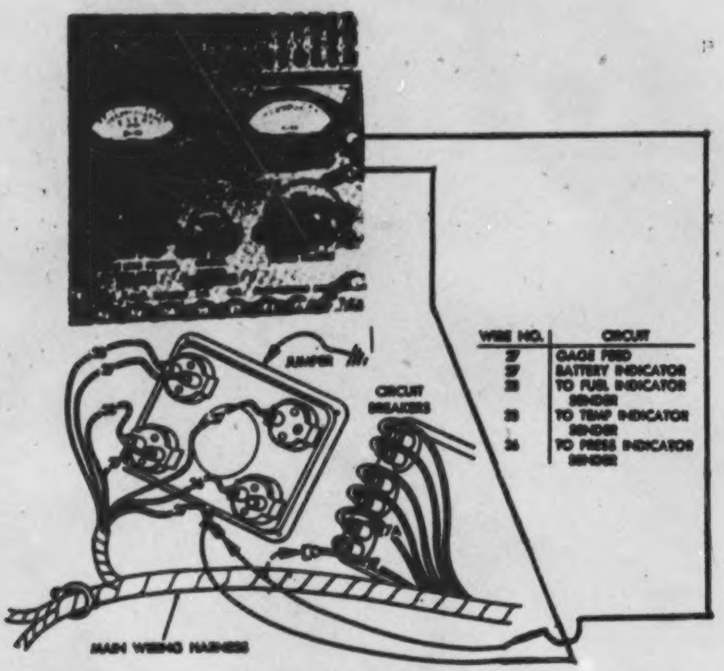
343

**10. CHECKING GAGES AND SENDING UNITS.** The proper place to start checking the electrical gages depends on the nature of the trouble. If none of the gages operate, start by checking wire number 27 from the ignition switch. With the switch on and the voltmeter connected as shown in the figure, the meter should read battery voltage. If it reads zero, disconnect wire number 10 at the ignition switch and connect the positive voltmeter lead to it. If the battery voltage reading is obtained, replace the ignition switch.



BATTERY-GENERATOR INDICATOR TEST

a. If the battery-generator indicator operates when the switch is turned on, but none of the other gages do, check circuit number 27A at the circuit breaker. The reasons we would start our test here are:


JUMPER
CIRCUIT BREAKERS
27A
MAIN WIRING HARNESS
WIRE NO.
CIRCUIT
27
GAGE FEED
27
BATTERY INDICATOR
28
TO FUEL INDICATOR SENDER
29
TO TEMP INDICATOR SENDER
26
TO PRESS INDICATOR SENDER

INDICATOR SYSTEM VOLTAGE TEST

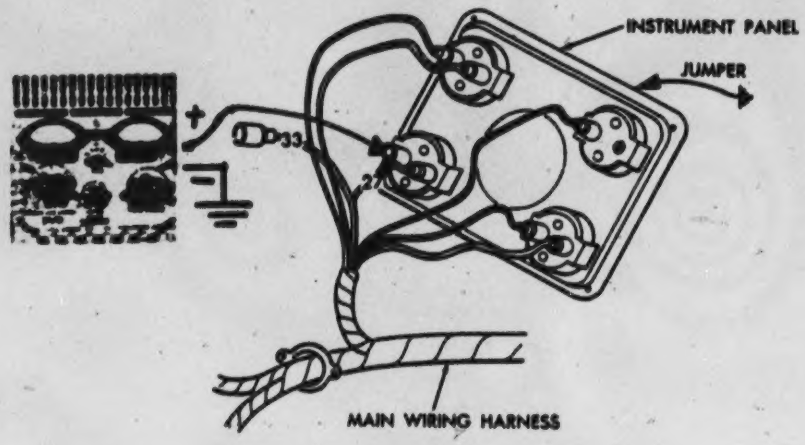
(1) Current is being supplied to circuit number 27 from the ignition switch, otherwise the battery-generator indicator would not work.

(2) The circuit breaker between wires 27 and 27A is in series with all gages except the battery-generator indicator. If it is open, the gages will not work.

(3) It is very unlikely that three gages would become defective at one time.

b. If all of the gages but one operate, remove the instrument cluster from the dash panel. Remember to use a jumper wire between the metal part of the instrument cluster and a good ground on the dash panel. Connect the positive voltmeter lead to the number 27 wire at the inoperative gage as in the preceding figure. Connect the negative voltmeter lead to ground. With the ignition switch on, the voltage reading should be battery voltage. If the meter reads zero, look for an open in the number 27 wire between the gage and the circuit breaker. Connect wire number 27 to the gage.

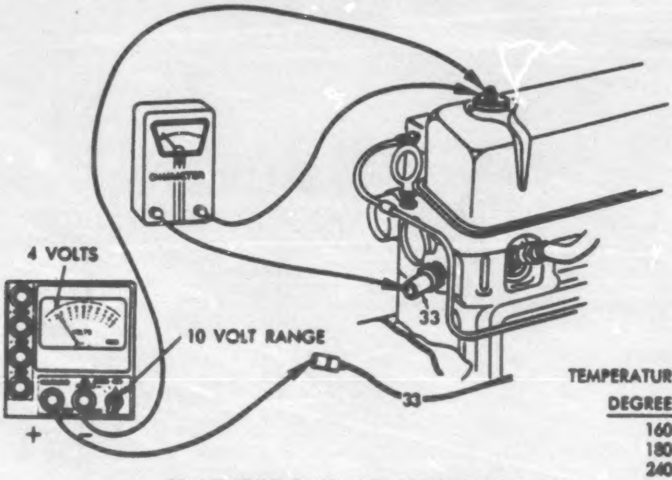
(1) Now connect the voltmeter as shown in this figure. This figure illustrates the connection to the temperature gage. The procedure would be the same at the oil pressure gage or the fuel gage. With the ignition switch on, the voltmeter should read 24 volts at the temperature gage and 3 to 4 volts at either the oil pressure or fuel gage.



(2) If a 24-volt reading was obtained at the number 27 wire, but a zero reading was obtained at the terminal on the gage that leads to the sending unit, replace the gage.

(3) If the gage is OK, connect the wire to the sending unit at the gage and disconnect the wire at the appropriate sending unit.

c. This figure illustrates the voltmeter connected to the water temperature sending unit and to the gage wire. With the ignition switch on, you should get the same voltage reading here that you got at the gage. If not, look for an open circuit or loose connection in the wire between the sending unit and the gage.



TEMPERATURE SENDING UNIT

| DEGREES (F) | OHMS |
|---|---|
| 160 | 1200 |
| 180 | 917 |
| 240 | 450 |

TEMPERATURE GAGE AND SENDING UNIT TEST

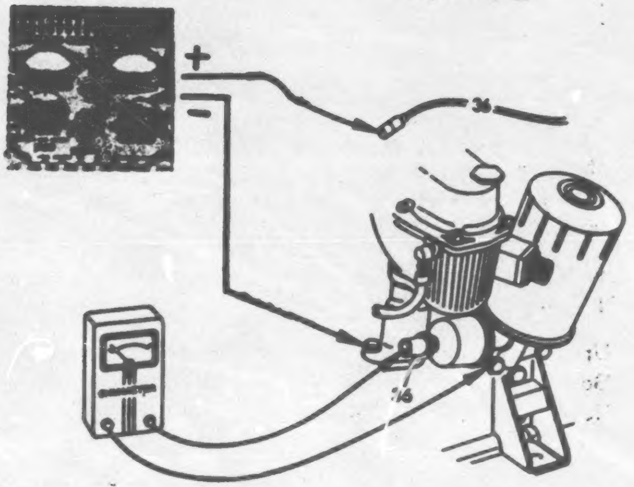
(1) If the sending unit to gage wire is OK on either of the gage circuits, check the sending unit with the ohmmeter section of the multimeter.

(2) The figure illustrates the procedure for checking the temperature sending unit. Notice on the chart in the illustration the values of the resistances in ohms for different water temperatures. To test the sending unit, place the multimeter selector switch in the 10,000 ohms position. Clip the two test leads together and turn the adjusting knob to zero the meter. Now connect the meter to the sending unit as shown in the figure. If the engine is cold, the ohmmeter should read more than 1,200 ohms. Crank the engine and allow it to warm up. Place a thermometer in the radiator to register the water temperature. Readings obtained on the ohmmeter should be within 5 percent of those shown on the chart in the preceding figure. If the readings obtained are unsatisfactory, replace the sending unit.

d. The oil pressure gage and sending unit test is illustrated in the accompanying figure.

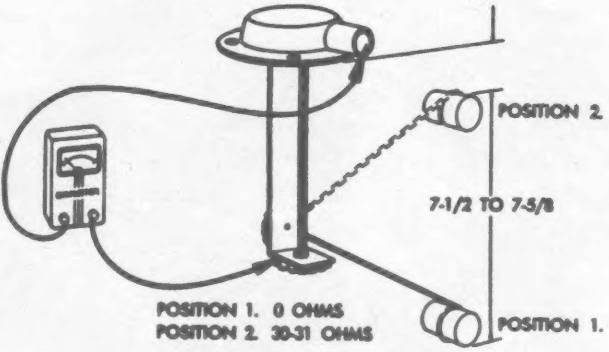
PRESSURE SENDING UNIT

| LB | OHMS |
|---|---|
| 20 | 8.5 TO 11 |
| 25 | 11 TO 13.5 |
| 30 | 14 TO 16 |
| 35 | 16.5 TO 17.5 |
| 40 | 19 TO 20 |



OIL PRESSURE GAGE AND SENDING UNIT TEST

e. The fuel gage sending unit must be removed from the fuel tank to be tested. For both the oil pressure and the fuel sending units use the 100-ohm position on the multimeter.



POSITION 1. 0 OHMS
POSITION 2. 30-31 OHMS

FUEL LEVEL GAGE AND SENDING UNIT TEST

f. The battery-generator indicator gage test is shown in paragraph 10. A reading of battery voltage should be obtained in the test illustrated when the ignition switch is on. If the test meter reading is battery voltage, but the indicator reads in the red or in the extreme right of the green, replace the indicator.

Note. - Complete exercises number 148, 149, and 150 before continuing to section III.

148. The water temperature sending unit is checked with

a. a voltmeter.
b. an ammeter.
c. an ohmmeter.

149. If none of the gages operates a check should be made on the

a. starter switch.
b. oil pressure switch.
c. ignition switch.

150. Where is the ground connected to complete the horn circuit on the M151 1/4-ton truck?

a. Upper steering column bushing
b. Bottom of the steering gear
c. Horn button snapring

## SECTION III. CONCLUSION

11. SUMMARY. In order to test electrical circuits, gages, and other devices the repairman must understand the following:

How gages and other electrical devices operate.
How to read wiring diagrams.
How to use test equipment.
How to interpret readings obtained with test equipment.
Where to start testing and why.
When and how to test circuits and electrically operated devices.

a. Nobody expects you to remember circuit wiring numbers, testing procedures, or what readings should be obtained when using meters. However, a good repairman is expected to be able to follow printed wiring diagrams and instructions in the technical manuals on test and repair procedures.

b. Practice using test equipment every chance you get. You can expect to make mistakes, but mistakes can be good teachers. You will learn only through practice.

12. **PRACTICE TASK LIST DIRECTIONS.** Appendix A contains a list of tasks associated with wheeled vehicle electrical systems. They are representative of tasks you will be required to perform as a wheeled vehicle repairman. Perform all of the tasks listed. Be sure you are under the supervision of an officer, NCO, or specialist qualified in the MOS when you practice the tasks. If you find you are having difficulty in certain tasks, restudy the appropriate training material and practice the tasks until you become proficient in each one.

## APPENDIX A

## PRACTICE TASK LIST

**Practice Objectives.** After practicing the following tasks you will be able to:

1. Use technical manuals to locate and identify wheeled vehicle electrical system circuits and electrical components.

2. Use an LVCT and a multimeter to test the light, horn, fuel pump, and gage circuits.

**Tasks.**

1. In order to test the electrical system of a wheeled vehicle, you must be able to use the vehicle's wiring diagram. You should be able to identify and trace the various circuits on this diagram and also trace current flow through them.

a. Before starting to use the test equipment to practice checking the system, study the wiring diagram in the technical manual for the vehicle on which you will make the tests. Here are a few things you should practice by using the schematic diagram.

b. Locate and trace the flow of current through:

(1) Headlights.

(2) Service taillights.

(3) Service stoplights.

(4) Blackout marker lights.

(5) Blackout stoplights.

(6) Horn circuit.

(7) Fuel pump.

(8) Fuel gage and sending unit.

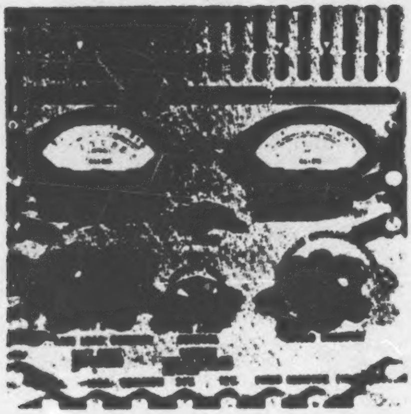
(9) Battery-generator indicator.

(10) Temperature gage and sending unit.

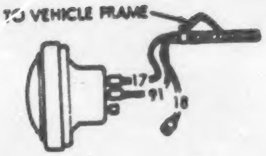
(11) Oil pressure gage and sending unit.

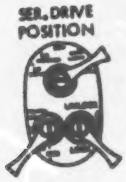
2. In order to become more familiar with the use of the LVCT, draw in the meter leads in the following diagrams.

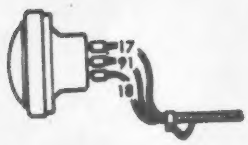
a. Draw in the meter leads as they should be connected to make a headlamp connector voltage test. After you have drawn in the leads, refer to the lesson to see if you are correct.



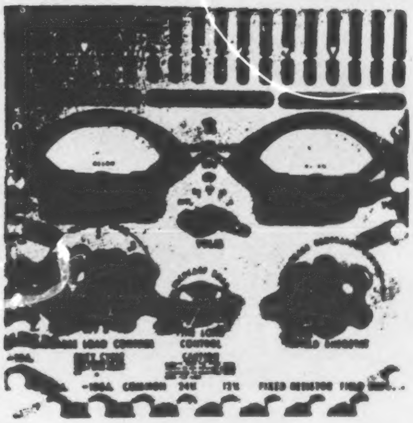
| WIRE NO. | CIRCUIT |
|---|---|
| 17 | HIGH BEAM |
| 18 | LOW BEAM |
| 91 | GROUND |

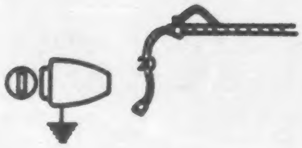

TO VEHICLE FRAME
17
91
18


SER. DRIVE POSITION

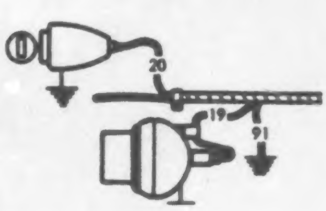


b. Draw in the meter leads as they should be connected to make a front blackout lamp connector voltage test. After you have drawn in the leads, refer to the lesson to see if you are correct.

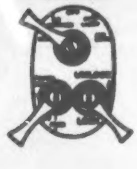

COMMON
24V
12V
FIXED RESISTOR



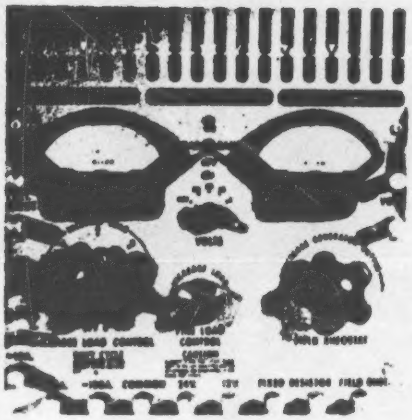
| WIRE NO. | CIRCUIT |
|---|---|
| 19 | B.O. DRIVE |
| 20 | B.O. MARKER |
| 91 | GROUND |



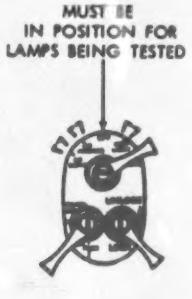
B.O. DRIVE POSITION

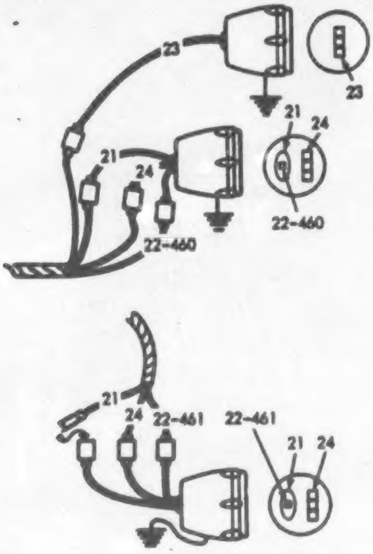


c. Draw in the meter leads as they should be connected to make a rear lamp connector voltage test. After you have drawn in the leads, refer to the lesson to see if you are correct



| WIRE NO. | CIRCUIT |
|---|---|
| 21 | SERVICE REAR LIGHT |
| 22-460 | SERVICE STOPLIGHT - RIGHT |
| 22-461 | SERVICE STOPLIGHT - LEFT |
| 23 | B.O. STOPLIGHT |
| 24 | B.O. REAR MARKER |


MUST BE
IN POSITION FOR
LAMPS BEING TESTED


23
23
21
24
21
24
22-460
22-460
21
24
22-461
22-461
21
24

3. When you feel you understand the wiring diagram well enough, practice making some of the tests. To do this you will need a wiring diagram for the vehicle to be tested, an LVCT, and an ohmmeter or multimeter.

a. Here are some of the circuits you should test:

(1) Service headlights and taillights.

(2) Service stoplight.

(3) Blackout lights.

(4) Blackout stoplight.

(5) Horn.

(6) Fuel pump.

(7) Fuel gage and sending unit.

(8) Battery-generator charge indicator.

(9) Temperature gage and sending unit.

(10) Oil pressure gage and sending unit.

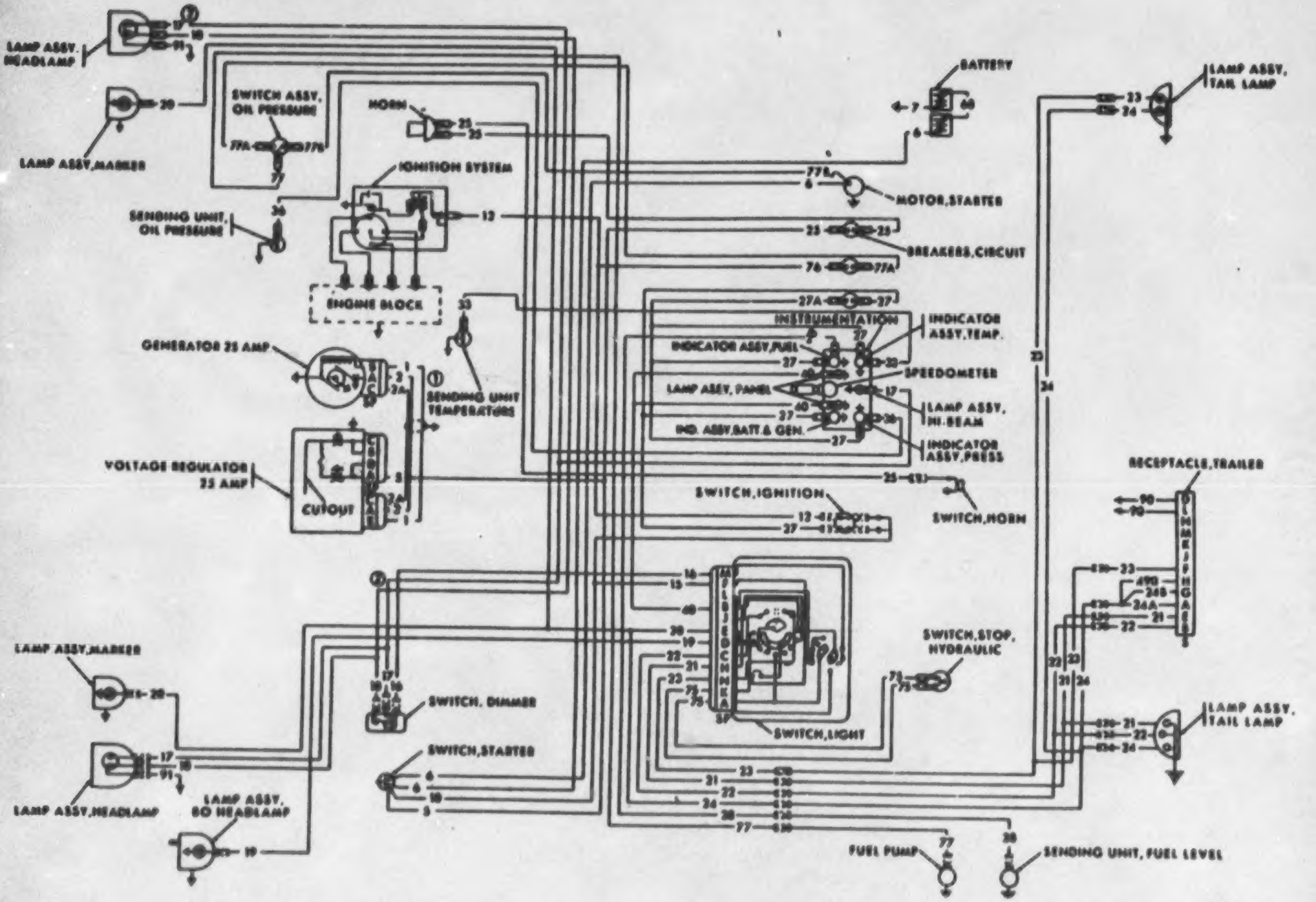
b. To become more familiar with the test procedures and test equipment, select a second vehicle, a different model than the first one, and perform the same tests on it.

## APPENDIX B

## REFERENCES

| | | |
|---|---|---|
| TM 9-8000 | Principles of Automotive Vehicles | Jan 56 |

☆ U. S. GOVERNMENT PRINTING OFFICE: 1974—620-219/2787 3-1


LAMP ASSY, HEADLAMP
LAMP ASSY, MARKER
SWITCH ASSY, OIL PRESSURE
HORN
IGNITION SYSTEM
SENDING UNIT, OIL PRESSURE
ENGINE BLOCK
GENERATOR 25 AMP
SENDING UNIT TEMPERATURE
VOLTAGE REGULATOR 25 AMP
CUTOUT
BATTERY
LAMP ASSY, TAIL LAMP
MOTOR, STARTER
BREAKERS, CIRCUIT
INSTRUMENTATION
INDICATOR ASSY, TEMP.
INDICATOR ASSY, FUEL
SPEEDOMETER
LAMP ASSY, PANEL
LAMP ASSY, HI-BEAM
IND. ASSY, BATT. & GEN.
INDICATOR ASSY, PRESS
SWITCH, IGNITION
SWITCH, HORN
RECEPTACLE, TRAILER
SWITCH, STOP, HYDRAULIC
SWITCH, DIMMER
SWITCH, LIGHT
SWITCH, STARTER
LAMP ASSY, MARKER
LAMP ASSY, HEADLAMP
LAMP ASSY, BO HEADLAMP
LAMP ASSY, TAIL LAMP
FUEL PUMP
SENDING UNIT, FUEL LEVEL

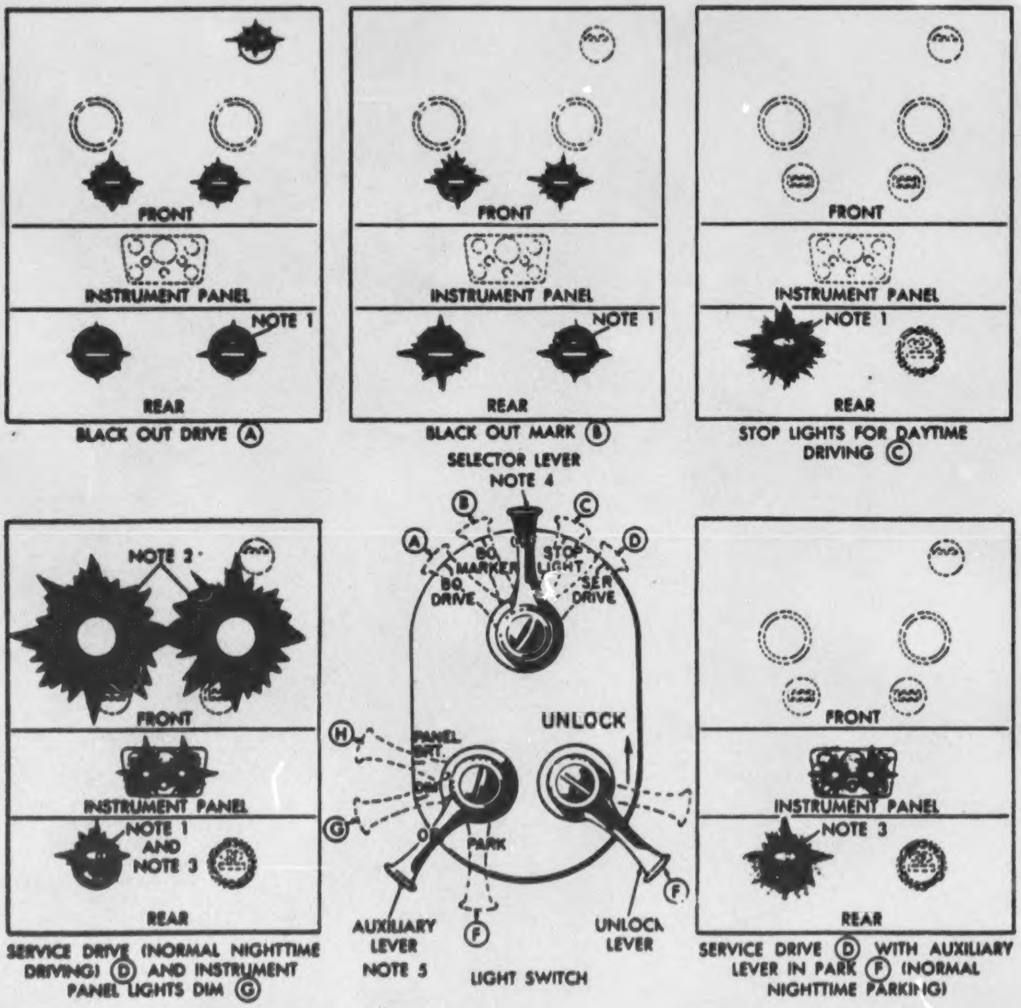
ORD E38935

Figure A. Vehicle electrical components, cable identification, and wiring diagram.

| Circuit No. | Circuit |
|---|---|
| 1 | Generator field circuit |
| 2 | Generator armature circuit |
| 3 | Generator armature circuit |
| 5 | Battery to regulator and splice through starter switch terminal |
| 6 | Battery to starter circuit |
| 7 | Battery to ground |
| 10 | Battery feed to instrument panel |
| 11 | Ignition switch feed |
| 12 | Ignition switch to ignition coil and splice |
| 15 | Main light switch feed |
| 16 | Light switch to dimmer switch |
| 17 | Dimmer switch to headlamp high beam |
| 18 | Dimmer switch to headlamp low beam |
| 19 | Lighting switch to blackout driving lamp |
| 20 | Lighting switch to blackout marker lamps |
| 21 | Lighting switch to service taillamp |
| 22 | Lighting switch to service stoplamp |
| 23 | Lighting switch to blackout stoplight |
| 24 | Lighting switch to blackout taillamp |
| 24A-24B | Blackout taillamp to trailer receptacle |
| 25 | Horn to horn switch |
| 27 | Instrument feed |
| 28 | Fuel gage to sending unit |
| 33 | Water temp gage to sending unit |
| 36 | Oil pressure gage to sending unit |
| 40 | Instrument lamp circuit |
| 68 | Battery interconnecting cables |
| 75 | Stoplight switch circuit |
| 76 | Fuel pump circuit feed |
| 77 | Fuel pump safety switch to fuel pump |
| 77A | Circuit breaker to fuel pump safety switch |
| 77B | Starter to fuel pump safety switch |
| 90 | Trailer receptacle to ground |
| 91 | Headlamp to ground |
| 490 | Clearance lamp blackout trailer feed |

Figure B. Identification of wiring circuit numbers.

Foldout illustration No 1


FRONT
INSTRUMENT PANEL
NOTE 1
REAR
BLACK OUT DRIVE Ⓐ
FRONT
INSTRUMENT PANEL
NOTE 1
REAR
BLACK OUT MARK Ⓑ
FRONT
INSTRUMENT PANEL
NOTE 1
REAR
STOP LIGHTS FOR DAYTIME DRIVING Ⓒ
SELECTOR LEVER NOTE 4
Ⓐ
Ⓑ
Ⓒ
Ⓓ
BO MARKER
STOP LIGHT
BO DRIVE
SER DRIVE
UNLOCK
Ⓗ
PANEL BRT.
DIM
Ⓖ
O
PARK
Ⓕ
Ⓕ
AUXILIARY LEVER NOTE 5
LIGHT SWITCH
UNLOCK LEVER
NOTE 2
FRONT
INSTRUMENT PANEL
NOTE 1 AND NOTE 3
REAR
SERVICE DRIVE (NORMAL NIGHTTIME DRIVING) Ⓓ AND INSTRUMENT PANEL LIGHTS DIM Ⓖ
FRONT
INSTRUMENT PANEL
NOTE 3
REAR
SERVICE DRIVE Ⓓ WITH AUXILIARY LEVER IN PARK Ⓕ (NORMAL NIGHTTIME PARKING)

NOTE 1. STOP LIGHT GOES ON WHEN BRAKES ARE APPLIED

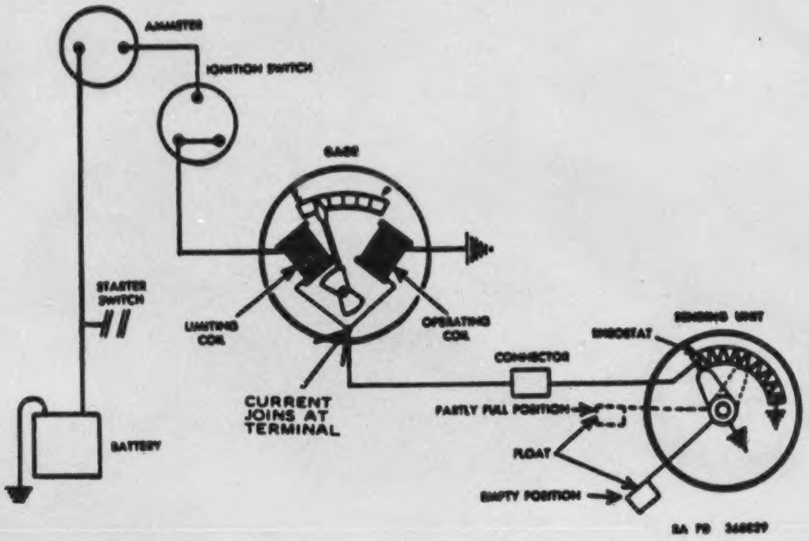
NOTE 2. DIMMER SWITCH OPERATES HI AND LO BEAM OF HEADLIGHTS WHEN IN SERVICE DRIVE Ⓓ

NOTE 3. TAIL LIGHT GOES ON

NOTE 4. TO PLACE SELECTOR LEVER IN BLACKOUT DRIVE Ⓐ, STOP LIGHT Ⓒ, OR SERVICE DRIVE Ⓓ UNLOCK LEVER Ⓔ MUST BE LIFTED TO UNLOCK POSITION. NO LIGHTS OPERATE WHEN SELECTOR LEVER IS IN OFF POSITION.

NOTE 5. INSTRUMENT PANEL LIGHTS ARE BRIGHT IN PANEL BRT Ⓗ POSITION. THE AUXILIARY LEVER CAN BE OPERATED AT ANYTIME IN ANY POSITION.

Foldout illustration No 2. Operation of light switch.


AMMETER
IGNITION SWITCH
GAGE
STARTER SWITCH
LIMITING COIL
OPERATING COIL
CURRENT JOINS AT TERMINAL
SENDING UNIT
RHEOSTAT
CONNECTOR
PARTLY FULL POSITION
FLOAT
EMPTY POSITION
BATTERY
RA PD 348839

Foldout illustration No 3. Coil-type fuel gage circuit.

# ORDNANCE SUBCOURSE 63B203
# WHEELED VEHICLE ELECTRICAL SYSTEMS

JANUARY 1976

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND, MARYLAND

## ANSWER SHEET

FOR STUDENT USE ONLY - DO NOT RETURN

| | a | b | c | | a | b | c | | a | b | c | | a | b | c | | a | b | c |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 104 | 501 | 536 | 41. | 437 | 523 | 333 | 81. | 246 | 405 | 460 | 121. | 625 | 346 | 515 | 161. | 428 | 613 | 114 |
| 2. | 223 | 667 | 566 | 42. | 349 | 639 | 274 | 82. | 360 | 440 | 624 | 122. | 484 | 256 | 399 | 162. | 201 | 552 | 443 |
| 3. | 421 | 308 | 243 | 43. | 277 | 394 | 647 | 83. | 600 | 365 | 122 | 123. | 217 | 666 | 436 | 163. | 509 | 373 | 660 |
| 4. | 241 | 483 | 527 | 44. | 539 | 496 | 668 | 84. | 233 | 526 | 339 | 124. | 334 | 503 | 139 | 164. | 180 | 481 | 230 |
| 5. | 375 | 166 | 612 | 45. | 113 | 408 | 382 | 85. | 586 | 282 | 271 | 125. | 563 | 398 | 291 | 165. | 357 | 272 | 564 |
| 6. | 690 | 110 | 427 | 46. | 522 | 397 | 298 | 86. | 176 | 684 | 488 | 126. | 111 | 660 | 331 | 166. | 586 | 396 | 174 |
| 7. | 582 | 290 | 420 | 47. | 191 | 642 | 412 | 87. | 434 | 150 | 675 | 127. | 633 | 252 | 479 | 167. | 343 | 151 | 666 |
| 8. | 630 | 197 | 463 | 48. | 356 | 662 | 253 | 88. | 651 | 363 | 164 | 128. | 216 | 438 | 528 | 168. | 120 | 519 | 495 |
| 9. | 679 | 143 | 661 | 49. | 500 | 379 | 416 | 89. | 225 | 474 | 672 | 129. | 411 | 198 | 671 | 169. | 626 | 246 | 314 |
| 10. | 647 | 686 | 342 | 50. | 118 | 493 | 204 | 90. | 400 | 138 | 362 | 130. | 568 | 169 | 398 | 170. | 467 | 652 | 203 |
| 11. | 289 | 578 | 231 | 51. | 164 | 415 | 533 | 91. | 371 | 535 | 202 | 131. | 368 | 667 | 275 | 171. | 286 | 433 | 540 |
| 12. | 636 | 408 | 236 | 52. | 629 | 196 | 620 | 92. | 613 | 208 | 446 | 132. | 144 | 467 | 666 | 172. | 618 | 156 | 361 |
| 13. | 429 | 396 | 636 | 53. | 311 | 506 | 498 | 93. | 105 | 664 | 643 | 133. | 476 | 502 | 123 | 173. | 473 | 658 | 249 |
| 14. | 103 | 112 | 628 | 54. | 167 | 239 | 323 | 94. | 644 | 282 | 464 | 134. | 602 | 258 | 450 | 174. | 211 | 586 | 499 |
| 15. | 119 | 336 | 178 | 55. | 304 | 442 | 227 | 95. | 387 | 618 | 181 | 135. | 229 | 303 | 598 | 175. | 182 | 351 | 661 |
| 16. | 610 | 276 | 452 | 56. | 631 | 360 | 580 | 96. | 169 | 374 | 606 | 136. | 168 | 441 | 305 | 176. | 308 | 466 | 598 |
| 17. | 236 | 382 | 524 | 57. | 677 | 206 | 426 | 97. | 667 | 127 | 332 | 137. | 472 | 680 | 125 | 177. | 538 | 265 | 105 |
| 18. | 101 | 490 | 362 | 58. | 389 | 402 | 147 | 98. | 410 | 619 | 212 | 138. | 389 | 157 | 576 | 178. | 445 | 187 | 648 |
| 19. | 521 | 391 | 368 | 59. | 316 | 638 | 403 | 99. | 247 | 461 | 587 | 139. | 534 | 380 | 244 | 179. | 153 | 542 | 312 |
| 20. | 628 | 378 | 426 | 60. | 194 | 563 | 288 | 100. | 328 | 561 | 186 | 140. | 676 | 221 | 401 | 180. | 234 | 656 | 458 |
| 21. | 486 | 124 | 582 | 61. | 383 | 570 | 477 | 101. | 199 | 301 | 614 | 141. | 287 | 589 | 606 | 181. | 670 | 283 | 560 |
| 22. | 641 | 492 | 242 | 62. | 284 | 367 | 109 | 102. | 683 | 131 | 459 | 142. | 364 | 696 | 189 | 182. | 302 | 430 | 148 |
| 23. | 326 | 133 | 567 | 63. | 207 | 545 | 648 | 103. | 431 | 607 | 260 | 143. | 641 | 297 | 499 | 183. | 574 | 317 | 240 |
| 24. | 293 | 465 | 637 | 64. | 422 | 138 | 568 | 104. | 281 | 480 | 612 | 144. | 163 | 666 | 389 | 184. | 166 | 348 | 564 |
| 25. | 248 | 330 | 288 | 65. | 615 | 604 | 417 | 105. | 561 | 286 | 318 | 145. | 646 | 322 | 297 | 185. | 326 | 663 | 261 |
| 26. | 152 | 296 | 423 | 66. | 146 | 497 | 218 | 106. | 116 | 507 | 238 | 146. | 226 | 449 | 614 | 186. | 622 | 179 | 464 |
| 27. | 298 | 601 | 643 | 67. | 580 | 205 | 376 | 107. | 601 | 222 | 419 | 147. | 418 | 130 | 609 | 187. | 662 | 269 | 618 |
| 28. | 673 | 380 | 432 | 68. | 621 | 177 | 663 | 108. | 414 | 190 | 669 | 148. | 506 | 396 | 198 | 188. | 208 | 617 | 327 |
| 29. | 537 | 213 | 264 | 69. | 468 | 668 | 320 | 109. | 366 | 611 | 172 | 149. | 294 | 604 | 408 | 189. | 585 | 413 | 107 |
| 30. | 182 | 264 | 117 | 70. | 134 | 497 | 694 | 110. | 687 | 439 | 329 | 150. | 424 | 168 | 363 | 190. | 377 | 673 | 132 |
| 31. | 681 | 471 | 341 | 71. | 386 | 448 | 170 | 111. | 140 | 381 | 589 | 151. | 646 | 219 | 548 | 191. | 136 | 319 | 461 |
| 32. | 279 | 617 | 324 | 72. | 200 | 566 | 307 | 112. | 394 | 667 | 193 | 152. | 128 | 583 | 264 | 192. | 683 | 186 | 370 |
| 33. | 601 | 677 | 292 | 73. | 674 | 184 | 616 | 113. | 610 | 118 | 586 | 153. | 321 | 463 | 676 | 193. | 494 | 251 | 525 |
| 34. | 280 | 679 | 298 | 74. | 567 | 290 | 662 | 114. | 149 | 447 | 209 | 154. | 171 | 364 | 620 | 194. | 544 | 469 | 232 |
| 35. | 347 | 672 | 129 | 75. | 228 | 608 | 161 | 115. | 462 | 335 | 623 | 155. | 663 | 237 | 464 | 195. | 287 | 530 | 649 |
| 36. | 156 | 604 | 278 | 76. | 372 | 141 | 666 | 116. | 338 | 669 | 404 | 156. | 436 | 692 | 146 | 196. | 668 | 263 | 455 |
| 37. | 179 | 663 | 401 | 77. | 649 | 666 | 210 | 117. | 108 | 224 | 300 | 157. | 660 | 102 | 337 | 197. | 315 | 160 | 632 |
| 38. | 466 | 664 | 188 | 78. | 444 | 220 | 313 | 118. | 666 | 664 | 142 | 158. | 310 | 632 | 270 | 198. | 137 | 611 | 340 |
| 39. | 215 | 634 | 482 | 79. | 696 | 550 | 173 | 119. | 308 | 121 | 640 | 159. | 214 | 176 | 571 | 199. | 569 | 383 | 280 |
| 40. | 467 | 637 | 366 | 80. | 100 | 344 | 531 | 120. | 183 | 470 | 273 | 160. | 676 | 162 | 348 | 200. | 478 | 689 | 128 |

| RESPONSE NUMBER | RESPONSE* |
|---|---|
| 100 | CORRECT. When mounted on the vehicle, the air cleaner sits directly over the alternator. It must be removed to make the generator accessible. |
| 101 | Para 15b(3) |
| 103 | Para 11b(2) |
| 104 | Para 2d |
| 106 | Para 7b |
| 108 | Para 5b(7) |
| 109 | Para 4a |
| 110 | CORRECT. They will always flow from a negative to a positive charge. |
| 111 | Para 8a |
| 112 | Para 11b |
| 113 | Para 3j |
| 115 | CORRECT. A heavy wire is not needed because only a small fraction of an ampere of current is carried by the wire. The voltage applied is very high, but a heavy wire is not needed unless the current carried is high. |
| 116 | Para 7a |
| 117 | CORRECT. The weight of water is 1.000; the acid is 1.835 pure. |
| 118 | CORRECT. When determining battery condition by measuring voltage, the battery should be under load. The starter motor will provide such a load. |
| 119 | Para 12b |

*If your response is not listed CORRECT, refer to the indicated paragraph for the proper answer.

121 Para 6a

122 Para 31

123 Para 2g

124 Para 17a(7)

125 Para 3 and 3a

127 Para 8

129 CORRECT. This will be true if you get a hydrometer reading from 1.200 to 1.225, but the battery should be used in tropical climate only.

130 Para 6e

131 CORRECT. Early model coils had the secondary grounded to the coil base, but modern practice is to ground the secondary to the primary winding.

133 Para 18c

134 CORRECT. The load bank is connected in series with the ammeter. During this test we want to see if the generator will produce its rated amount of current. With the load bank we can control the amount of resistance in the charging circuit and limit the generator output to 25 amperes.

136 Para 5b(4)

138 CORRECT. The pole shoes (also called pole pieces) become electromagnets when current is sent through the field windings, which are wrapped around the pole shoes.

139 CORRECT. Never bend the center electrode; if you attempt to do so, you will break the porcelain insulator.

140 Para 2

141 CORRECT. The diodes are much smaller than the metallic plate type rectifiers used with the 100-ampere alternator.

142 Para 5b

143 Para 8

144 CORRECT. The numbers used to identify the wires in the Army's identification system are stamped on small metal tags that are attached to the wires.

145 Para 5c

147 Para 11h

149 Para 3d

150 Para 3f and 3g

152 Para 2

154 CORRECT. When a small gear is driving a large gear, it is usually referred to as a pinion gear.

156 Para 12

157 Para 5b

158 Para 8a(5)

159 Para 8

161 Para 10c

163 Para 6

164 Para 7d

166 Para 5c(5)

167 CORRECT. We need the two heavy battery leads to carry the current in the circuit being tested. A small part of this current is shunted off through the two small leads to give us a reading on the ammeter of the LVCT.

168 Para 2n

169 CORRECT. It is not likely that you installed the distributor so that the engine is in perfect time.

170 CORRECT. The particular type of spanner used to remove the wiring harness is the hook spanner. It is also used to disconnect the wiring harness at the regulator.

172 Para 6a

173 CORRECT. The vehicle has a 24-volt electrical system, but the generator must produce more than that in order to charge the batteries.

175 Para 3f

177 Para 7d(3)

178 CORRECT. This is expressed by the number of ohms of resistance the item has.

179 Para 15

181 CORRECT. We should drop very little voltage through the ground circuit. If the reading is much above 0.1 volt across the ground circuit, look for loose starter mounting bolts and loose, frayed, or corroded ground straps between the starter and battery ground post.

183 Para 6b

184 CORRECT. The rotor contains the electromagnets which furnish the moving magnetic fields that induce the current into the stator windings.

186 Para 7

188 Para 15

189 Para 5i

190 Para 5b

191 Para 4g

192 Para 4

193 Para 2d

194 Para 10 and 12

195 Para 7d

196 CORRECT. The resistance in the sending unit will vary from about 1,200 ohms when the engine is cold to about 450 ohms when the engine is hot.

197 Para 7a

198 CORRECT. The ignition system would work just as well without this capacitor. Its only purpose is to provide some interference suppression for the radio.

199 Para 1c(1)

200 Para 9

202 CORRECT. If the pinion drives in a clockwise direction, it will disengage the overrunning clutch when turned counterclockwise. Overrunning clutches are characterized by the fact they will drive in one direction only.

204 Para 7a

205 CORRECT. High voltage can cause the battery to be overcharged. The voltage regulator keeps the generator voltage from getting high enough to overcharge the battery.

206 CORRECT. The ohmmeter is part of a tester called the "multimeter." The multimeter also includes a voltmeter and milliammeter. Remember, however, that the word "milli" means in thousandths (1/1,000), so the ammeter cannot be used on most automotive circuits.

207 CORRECT. This is the rotating member in the 25-ampere generator. It is rotated by the pulley, which, in turn is rotated by the drivebelts. These belts may also drive the water pump and/or other accessories.

209 CORRECT. When making a continuity check with a voltmeter, current must be able to flow at the point of the check. If current is to flow at the distributor input, the ignition switch must be ON (closed).

210 CORRECT. The actual regulator is a stack of carbon disks which are pressed together by spring pressure. Reducing the spring pressure increases the electrical resistance of the carbon pile. Then the amount of current flowing through it is reduced.

212 CORRECT. Loose starter motor mounting bolts can allow misalinement of the starter pinion and flywheel ring gear. Such action can cause the pinion teeth to break, or even worse, cause the flywheel gear teeth to break.

213 Para 7a

215 CORRECT. Providing the electrolyte temperature is 110° F or less.

216 Para 8c

217 Para 7a

218 CORRECT. When the generator is producing the maximum current, it gets too hot. The current regulator cuts back the field current and thus protects the generator against overloads which could cause it to burn out.

220 Para 11b

221 CORRECT. The battery-generator indicator is really a voltmeter. The gage has only one coil, which is grounded to the instrument cluster.

222 Para 5b

223 Para 5b

224 CORRECT. If the spring tension is too weak it can't close the points fast enough. As a result, dwell decreases and the meter needle will move to the left.

225 Para 5c

226 Para 3a

227 Para 7d

228 CORRECT. A circuit breaker is used in the generator regulator for a DC generator, but no such device is used in the alternator regulator.

229 CORRECT. The diaphram moves so rapidly back and forth, as the coil magnetizes and demagnetizes, that it actually vibrates and produces the sound we hear when the horn blows.

231 CORRECT. The word "potential" may also be used.

233 Para 3k

235 Para 9

236 Para 14b

238 Para 5a

239 Para 7e

240 Para 17a(14)

241 Para 4c

243 Para 5c(2)

244 Para 5f

245 CORRECT. The starting motor changes the electrical energy from the battery into the mechanical energy needed to turn the engine's crankshaft.

247 Para 7b

248 CORRECT. This may be caused by corroded battery terminals, loose connections, or frayed wires.

250 Para 3e

252 CORRECT. Remember, this resistor is in series with the primary circuit and drops the voltage applied to the coil and points. On Autolite models the resistor is located inside the coil.

253 Para 4p

255 Para 7a

256 CORRECT. The method used to determine the ampere-hour capacity of automotive batteries is the 20-hour rate.

257 Para 6c

259 Para 13

260 Para 9e

262 CORRECT. If the starter is not in operation, full battery voltage would be applied to the 1-volt scale of the voltmeter. This would damage the meter.

264 Para 4

266 CORRECT. The additional gear reduction will increase the torque applied to turn the engine. So we can use a smaller starter motor than might otherwise be required. Don't forget, however, that we always sacrifice rotational speed to get the additional torque.

268 Para 11 and 12

271 CORRECT. Magnetic lines of force will bend before they will cross each other. This is the cause of replusion.

273 CORRECT. The timing marks on the crankshaft pulley or vibration damper indicate when the number 1 cylinder is at or near TDC (top dead center). If there is only one mark, the distributor should be timed to it.

274 CORRECT. Watches and rings are good conductors of electricity and can be damaged beyond repair if they become part of an electrical circuit. A repairman can get shocked or burned by the watch or jewelry he may be wearing if they come in contact with a live circuit.

275 Para 2

276 Para 13

277 Para 2d

278 CORRECT. This will occur only on vehicles with AC generators, but you must be very careful when connecting the cables to all vehicles as damage can also occur to other parts.

279 Para 9

281 CORRECT. The pigtail lead of the capacitor is connected to the same terminal in the distributor as the movable breaker point. Thus, current could flow to either the points or the capacitor.

282 Para 3b

284 CORRECT. All the DC generators used in military vehicles are shunt wound. Part of the current induced in the armature windings is shunted (sent off in a parallel circuit) to the field windings to excite the circuits.

286 Para 4b

287 CORRECT. Most of the current will be flowing through the operating coil, because the contact arm in the sending unit will have moved to the point so that current flowing through it will have to go through the rheostat.

288 Para 19d

289 Para 10

290 CORRECT. Material of this nature allows electric current to flow through it easily.

291 Para 8

292 CORRECT. Apply a light coat of grease (GAA) to terminals and clamps after cleaning.

293 Para 19c

294 Para 10

295 CORRECT. The active material that is used to make the battery work is not strong enough by itself to withstand the bouncing the battery gets in the vehicle.

296 CORRECT. For every 10° above 80° we add four points to the hydrometer reading. We go in the opposite direction, subtracting four points, for each 10° under 80°.

297 CORRECT. The battery-generator indicator is mounted in and grounded to the instrument cluster. Whenever the cluster is pulled away from the dash, a jumper wire should be used to maintain the ground circuit to the dash.

298 Para 13

| | |
|---|---|
| 299 | CORRECT. Remember, the vehicle's batteries must be disconnected when using the ohmmeter. |
| 300 | Para 5b(7) |
| 301 | Para 1c(1) |
| 303 | Para 4 |
| 304 | Para 7d |
| 305 | Para 2n |
| 306 | Para 6a |
| 307 | Para 9 |
| 309 | CORRECT. The third and remaining group of charged particles circle around the two groups listed in this choice. |
| 311 | CORRECT. The shunt must be used whenever the amperage is over 100 amps. |
| 313 | Para 11b |
| 316 | Para 11b |
| 318 | Para 4b |
| 320 | Para 6a |
| 322 | Para 6c |
| 323 | Para 7e |
| 324 | Para 9 |
| 326 | Para 18c |
| 328 | Para 7 |
| 329 | Para 6a |
| 330 | Para 19d |

| | |
|---|---|
| 331 | CORRECT. If you get a strong blue spark when performing this test, the distributor is probably OK. The next step would be to check the spark plug. |
| 332 | Para 8 |
| 333 | Para 2 |
| 334 | Para 7f |
| 335 | Para 3f(4) |
| 336 | Para 12b |
| 338 | Para 3g |
| 339 | Para 3k |
| 341 | Para 8 |
| 342 | Para 8 |
| 344 | Para 19d |
| 346 | Para 6f |
| 347 | Para 11 |
| 349 | Para 2 |
| 350 | CORRECT. The others might work with a very low flow; however, they would be damaged if used throughout most of the range. |
| 352 | Para 5b(4) |
| 353 | Para 8a(5) |
| 354 | Para 5i |
| 355 | CORRECT. The weights are mounted on this base and cause the camshaft to advance as the weights move outward. |
| 356 | Para 10 |
| 358 | CORRECT. You used the formula in the lesson correctly. |

359 CORRECT. An air pressure gage is added to the instrument cluster on any military vehicle with air or air-over-hydraulic brakes. In addition, a warning buzzer is also installed. It sounds off any time the air pressure is dangerously low.

360 Para 3h

362 CORRECT. This is because the lines of force of the two magnets are flowing in the same direction as they combine.

363 Para 5

365 Para 21

367 Para 4a

368 Para 2

369 CORRECT. This will determine which end of the magnet will be the north pole, but will not affect its strength.

371 Para 5c(2)

372 Para 12

374 CORRECT. This is an unusual location for a starter motor. Most of them are mounted on the side of the engine. Even though it is mounted on the upper right side of the transmission, the starter motor, like most others, is bolted to the flywheel housing so the pinion gear can engage the flywheel gear.

375 CORRECT. The electrical charge is always determined by the balance of electrons and protons.

376 Para 5d

378 CORRECT. This device has no moving parts and depends upon the building up and collapsing of the magnetic lines of force to make it operate.

379 Para 6

380 Para 5f

381 Para 2

382 CORRECT. If only one of these parts is used, one-half of the alternating current will be allowed to pass causing a pulsating DC.

384 CORRECT. There is a positive flow of air through the distributor that will remove moisture and other crankcase vapors that seep into the distributor housing. The vapors removed are drawn into the intake manifold and then sent to the combustion chamber where they are burned with the fuel-air mixture.

385 Para 7c(2)

386 CORRECT. The complete pump is submerged in the gasoline in the fuel tank. It is a plunger-type pump that is operated electrically.

387 Para 7b

388 Para 8a

389 Para 11h

390 Para 3

391 Para 16a(2)

392 CORRECT. This shortens the length of the conductor in the component and decreases the resistance.

393 Para 1

394 CORRECT. The voltmeter is always connected in parallel with the circuit being tested. If it is connected in series, the current flow in the circuit will be cut considerably because the voltmeter is a high resistance unit.

395 Para 10c(1)

396 CORRECT. This item is often used in test instruments and controls for other electrical devices, so the operator can adjust the current flow by turning a knob.

397 Para 4e

398 Para 9b

399 CORRECT. These deposits will be a dry ash on the insulator nose; but don't worry about such plugs, they are doing their jobs.

400 CORRECT. The Folo-Thru drive will keep the pinion engaged with the flywheel ring gear until the engine is turning about 400 RPM. The drive thus protects the starter and, at the same time, keeps the pinion engaged until the engine is running.

401 Para 5e

402 CORRECT. When checking the resistance in a circuit, the farther to the left the needle moves the greater the resistance. If the needle deflects all the way to the left, it indicates infinite resistance which is an open circuit.

403 CORRECT. You multiplied the indicated reading by the selected position and got the actual resistance being measured.

404 Para 3g

405 Para 2

406 CORRECT. All of the gage circuits are fed by the number 27 wire from the ignition switch; so, if none of the gages work, we would want to find out if the ignition switch was supplying current to wire 27.

407 Para 5c

408 Para 3j

409 Para 9

410 Para 9

411 Para 8f

412 CORRECT. With the two lead wires clipped together, you move the ohms adjust knob back and forth until the meter reads 0 ohms. This adjustment eliminates the resistance in the leads from consideration when checking a circuit on a vehicle.

414 Para 5b

415 CORRECT. The four rows of numbers cover ranges from 0 to 1 volt, 0 to 10 volts, 0 to 20 volts, and 0 to 50 volts. Remember, when checking a circuit to put the voltage range selector switch in a high enough position to cover the voltage you are likely to encounter.

416 CORRECT. All five models currently being issued have the same NSN. You may get any one of the five when you order an LVCT.

417 Para 5c

418 CORRECT. There should be no voltage at the pump because the oil pressure switch would be open and no current would flow from the ignition switch to the pump.

419 CORRECT. The distance between the insulated and grounded electrodes is normally about 0.025 to 0.040 of an inch. This gap is commonly called the airgap.

420 Para 7a

421 Para 5c(2)

422 Para 3a

423 Para 2

424 CORRECT. This bushing should be checked if the horn won't blow when the horn switch is closed, but will blow when a jumper wire is connected to ground.

425 Para 9

426 Para 16c(2)

427 Para 6

429 Para 11b

431 Para 3e

432 Para 3

434 Para 3f and 3g

436 Para 7a

437 CORRECT. The voltmeter measures the electrical pressure. Remember, electrical pressure is another name for the voltage (or potential) in a circuit. Also, remember, that voltage is lost in overcoming the resistance in a circuit.

438 CORRECT. On vehicles with a waterproof ignition system, the coil is in the distributor and the distributor cover must be removed to gain access to the coil's secondary terminal.

439 Para 6a

440 CORRECT. To get continuous rotation, the direction of current flow through the loops in the armature must be reversed. This current reversal usually takes place every 90° of loop rotation. It is the job of the commutator and brushes to reverse the current flow in the loops.

441 CORRECT. The circuit breaker does the same job in a circuit that the ordinary fuse does. However, the circuit breaker can be reset, whereas the fuse is a one-time proposition.

442 CORRECT. The voltmeter used with the LVCT has four range scales, and the maximum scale reads from 0 to 50. These four scales enable us to check all circuits except the secondary circuit in the ignition system.

444 CORRECT. This adjustment can be made without disassembling the regulator; however, the range of adjustment allowed by this rheostat is small.

446 Para 5d

447 Para 3d

448 Para 7c(2)

449 Para 3a

450 CORRECT. The wires leading into or out of the receptacles are numbered, but the openings in the receptacles are identified by letters.

451 CORRECT. If the voltage drops to less than 18.5 volts while the starting circuit is being checked, one of the batteries is probably weak. To find out which one, check them separately. Be sure the starting motor is operating while you check each battery.

452 Para 13

454 Para 7b

457 CORRECT. This will prevent any further damage, but it must be followed up by charging the battery to make sure that the specific gravity is high enough to prevent the battery from freezing again.

459 Para 3b

460 Para 2

462 CORRECT. If the LVCT is bridging a section of the ignition circuit that is open, the voltmeter will indicate battery voltage (24 volts). This is too much voltage to register on the lesser scales.

463 Para 7a

465 CORRECT. The age of the battery is figured from this date. The normal life expectancy of a battery in an Army vehicle is 24 months.

467 Para 2b, c, and d

468 CORRECT. The battery indicator is color coded and, during vehicle operation, if the pointer stays in the lower green portion of the indicator, the battery and charging circuit are probably OK.

470 Para 6b

471 CORRECT. This is done by a series-parallel connection.

472 Para 3 and 3a

474 Para 5c

476 Para 2g

477 CORRECT. Flexible rubber belts are the most common means of driving the generator or alternator. The belts need to be checked fairly often to see if they are serviceable and properly adjusted.

479 Para 8b

480 Para 4b(5)

482 Para 14

483 CORRECT. Positive, plus, and (+) refer to the opposite charge.

484 Para 7a

485 CORRECT. However, this is not always a defect, as this is what happens when a switch is turned to the OFF position.

486 CORRECT. Sometimes this figure may have "ALT," the abbreviation for alternator, printed on it.

488 CORRECT. The strength of the magnetic field around a current carrying wire is proportional to the current flowing through the wire.

490 Para 15b(3)

491 Para 15

492 Para 17a(14)

493 CORRECT. We need the minus numbers to the left of the 0 in order to measure reverse current.

496 Para 3a

497 Para 7d(2)

498 Para 7e

499 Para 5i

500 Para 6

501 Para 2d

502 CORRECT. The rubber grommets are squeezed tightly around the wires when the two halves of the bell connector are locked together. When properly installed, the connection will be waterproof.

503 Para 7f

504 CORRECT. The output of the DC generator is controlled by the strength of the magnetic field. It could be controlled in other ways such as controlling the speed of the engine, but controlling the strength of the magnetic field is the most practical way.

505 Para 7e

506 Para 10c(1)

507 Para 5a

508 Para 3a

510 CORRECT. How often it does this in 1 second is called the frequency of the current and is expressed in cycles or Hertz, such as 60 Hertz (cycles).

512 Para 4b(5)

513 Para 5d

514 CORRECT. The BO markers are the only lights that can be turned on without moving the unlock lever.

515 Para 6f

516 Para 9b and c

518 Para 7b

520 Para 7d

521 Para 16a(2)

522 Para 4e

523 Para 2

524 Para 14

526 CORRECT. The Army does use starter motors that are compound wound, but most of the motors are series wound.

527 Para 4c

528 Para 8c

529 CORRECT. This term refers to the amount of resistance encountered by current flow.

531 Para 19a

533 Para 7d

534 CORRECT. The float will rise and fall as the level of the fuel in the tank rises and falls. As it moves, the float moves the contact arm in the sending unit. Thus, it varies the amount of current flowing through the rheostat and contact arm.

535 Para 5c(2)

536 CORRECT. This choice covers the use of electricity regardless of the job it's doing; i.e., heating, lighting, or driving a motor.

537 Para 7a

539 Para 3a

541 CORRECT. When placed in a schematic diagram, they are also accompanied by a number giving the ohms of resistance.

543 Para 7

545 Para 8a(4)

546 CORRECT. This switch is in series with the circuit between the ignition switch and fuel pump. It is normally held closed by the engine oil pressure when the engine is running. If the oil pressure drops below its set level, it opens and breaks the circuit between the ignition switch and fuel pump.

547 CORRECT. This substance will very often get on some electrical connections in an automotive vehicle and it will have to be removed or a high resistance connection will occur.

549 Para 10

551 CORRECT. We always check the battery and cables before making any electrical tests on the starter and its circuits. In fact, the starter cannot be satisfactorily tested unless the batteries and cables are in good condition.

553 CORRECT. It is generally in a lower range in the LVCT and goes to a very high range on most multimeters.

555 CORRECT. The AC charging system will produce a greater output at low engine speed than the DC system will. The alternator is, therefore, used on tactical vehicles to power vehicle mounted radio transmitters. Because it will produce considerable current flow at low engine speeds, its operation is less noisy. This is an important feature in many tactical situations.

556 Para 3b

557 CORRECT. If the battery ground strap is still connected while removing starter system components, there is a good possibility that a fire can start from the live wires you disconnect from the starter system components. There is also the possibility of burned fingers, melted wrenches, or electrical shock.

558 Para 9b

559 Para 11b

561 CORRECT. The spring, which is part of the movable point, closes the points as soon as the cam loses contact with the rubbing block.

562 Para 7a

563 CORRECT. The battery should always be charged if possible, but under certain conditions it may be used without charging.

565 Para 3b

567 Para 9e

569 CORRECT. Although the other possible answers could cause an engine breakdown, this system is far more likely to be the cause. This is one reason why it is so important that you understand the ignition system.

570 Para 1

572 Para 11

573 CORRECT. At the same time, the electrolyte is getting stronger and the negative plate is changing from lead sulfate to spongy lead.

575 CORRECT. Magnetic repulsion causes the armature to rotate in the magnetic field produced by the field windings and pole shoes.

576 Para 5b

577 Para 9b(1)

578 Para 10

579 Para 8

580 Para 5d

581 Para 8

582 Para 17a(7)

584 Para 15

587 Para 7b

589 Para 5f

590 Para 8

591 Para 5e(2)

593 CORRECT. You may have to make the other checks listed, but this is the simplest and best place to start, especially on waterproof ignition systems.

594 Para 12

595 CORRECT. Matter containing two or more elements is referred to as a compound.

596 Para 6

597 CORRECT. In this circuit, all the current flows through part of the load and then divides to flow through the rest of the load.

598 Para 4

599 CORRECT. Points that are too close will stay closed too long and thus increase the amount of cam dwell. To reduce the dwell, increase the point gap.

600 CORRECT. The armature windings or loops are mounted in grooves in the armature core. The ends of the loops are connected to the commutator bars.

601 Para 5b

602 Para 2i and j

603 Para 7d(3)

604 Para 10

605 Para 8

606 Para 5f

607 CORRECT. The rapid collapse of the magnetic field in the coil will induce a very high voltage in the secondary winding. This voltage will cause a spark to jump the gap in the spark plug.

608 Para 10c

609 Para 6

610 Para 3b

611 Para 6a

612 Para 5c(5)

614 CORRECT. One-half of the total number of cylinders will fire during each revolution of the engine. So the engine RPM will be equal to one-half of the total sparks per minute (1,600 ÷ 2 = 800).

615 Para 5c

617 CORRECT. However, when adding water always fill according to the instructions located on the battery top or vent plugs.

619 Para 9

621 CORRECT. The action of polarizing the generator is also known as "flashing the fields." This action establishes the residual magnetism in the field pole shoes.

623 Para 3f(4)

624 Para 3h

625 CORRECT. If the advance mechanism is working, the mark on the crankshaft pulley should move counterclockwise when the engine is speeded up.

627 Para 10

628 Para 16c(2)

629 CORRECT. The whole numbers are used as fractions of a volt. Each number, therefore, becomes a tenth of a volt.

630 CORRECT. This is because of the cost.

631 Para 8

633 Para 8b

634 Para 14

635 CORRECT. It takes more than 6-billion electrons moving past a given point in one second to make one ampere.

636 Para 11b

637 Para 19c

638 Para 11

639 Para 2a

640 CORRECT. Vibration dampers are commonly used on in-line engines with six or more cylinders. The timing marks are sometimes placed on these dampers.

641 Para 5i

642 Para 4q

643 Para 5e(2)

644 Para 7b

647 Para 2d

648 Para 8a(2)

650 Para 8a

651 Para 5

654 CORRECT. The external shunt makes it possible to check circuits in which up to 500 amperes of current are flowing. Without the external shunt, the capacity of the ammeter on the LVCT is 100 amperes.

656 Para 2b, c, and d

657 Para 5b

659 CORRECT. A spark plug with a short insulator nose will run cooler. At high speeds the engine runs hotter and a spark plug with a long insulator nose would probably be ruined in a short time.

661 CORRECT. Its weight and flexibility would be considered to fit the particular use.

662 Para 4p

664 Para 5b

665 Para 10

666 CORRECT. When making a voltage drop test, the meter should indicate voltage loss. This loss is slight if the points are closed, but is equal to battery voltage if the points are open.

667 Para 2d

669 Para 6a

671 Para 8a

672 CORRECT. The overrunning clutch type of drive is splined to the armature shaft. It can move forward or backward on the splines to engage or disengage the flywheel ring gear.

674 Para 9b and c

675 Para 5e

677 Para 9

679 CORRECT. With the batteries connected in parallel, their total voltage is no more than one battery by itself. A voltage source less than this amount will not charge the batteries; however, if the batteries are connected to a source with voltage that is too high, they will overheat.

680 CORRECT. Current for all the standard light circuits is controlled by the main light switch. If directional lights have been added, an extra switch is used for them.

682 CORRECT. In the 100-ampere alternator these phases are connected in the form of the letter Y. In the small alternator the phases are delta connected - like a triangle.

684 Para 3f

685 Para 8

687 CORRECT. This mechanism consists of spring-loaded weights which move and advance the distributor cam as the engine speeds up. The other types of mechanisms listed as possible answers are found on many civilian vehicles, but not on the Army's tactical wheeled vehicles.

688 Para 11b

690 Para 6a

691 Para 9b(1)

693 Para 3b

694 Para 7d(2)

695 CORRECT. The battery-generator indicator is really a voltmeter. When the indicator needle is over the green section on the face of the meter, the battery is being charged and the generator is probably OK.

696 Para 12

697 CORRECT. By having the wires grouped together in a single harness, the job of installing or securing the wires in place is made much easier.

698 CORRECT. A plug that is too cold will soon be fouled by carbon and unburned oil from the combustion chamber.

699 CORRECT. Many automotive electrical components have the amount stamped on them.

# US ARMY ORDNANCE CENTER AND SCHOOL
# CORRESPONDENCE/OJT COURSE

VERSION 1

## EXAMINATION

**Ordnance Subcourse No** 63B203. . . . Wheeled Vehicle Electrical Systems

**Credit Hours** . . . . . . . . . . . One

**Objective** . . . . . . . . . . . . . To test the student's overall knowledge of material covered in this subcourse.

**Suggestions** . . . . . . . . . . . . Before starting this examination, review all lessons studied in this subcourse.

**Texts** . . . . . . . . . . . . . . . All study texts used in this subcourse.

**Materials Required** . . . . . . . . . None

REQUIREMENT—50 MULTIPLE CHOICE QUESTIONS—Weight 100—All items are weighted equally.

1. What is indicated if the battery voltage is 20 volts while the engine is being cranked?

   a. Starting circuit is good
   b. Circuit resistance is high
   c. Batteries are discharged
   d. Circuit resistance is low

389

2. "Flashing the field" will restore polarity to the

   a. vehicle batteries.
   b. generator regulator.
   c. DC generator.
   d. AC generator.

3. What is probably at fault if the vehicle batteries are being overcharged?

   a. Worn generator brushes
   b. Improperly adjusted current regulator
   c. Worn commutator bars
   d. Improperly adjusted voltage regulator

4. If the ohmmeter hand points to the infinity symbol on the scale when connected to a circuit, the circuit

   a. has no resistance.
   b. is open.
   c. has little resistance.
   d. is shorted.

5. Why does the LVCT ammeter scale have numbers both right and left of zero?

   a. So the meter can be used to measure alternating current
   b. To prevent damage to the meter if the leads are accidental reversed
   c. So current flowing in either direction can be measured without reversing the leads
   d. To allow either of the meter leads to be connected to the negative terminal

6. All charging systems on military vehicles use a

   a. current regulator.
   b. circuit breaker.
   c. voltage regulator.
   d. load relay.

7. When the dwellmeter reading is greater than the recommended amount, which statement concerning the breaker points is correct?

   a. Spring tension is too strong
   b. Gap is too small
   c. Points are pitted
   d. Points open too soon

8. Arcing of the ignition breaker points is reduced by the

    a. capacitor action.
    b. secondary resistance.
    c. collapsing field.
    d. transformer action.

9. The spring tension of the moveable contact points should be checked with the points in what position?

    a. Fully closed
    b. Fully open
    c. Just closing
    d. Just opening

10. The battery cable will most likely be removed when checking the

    a. generator output.
    b. specific gravity.
    c. starter current.
    d. electrolyte level.

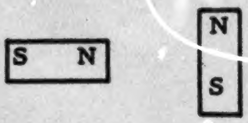
11. Which part of the LVCT should be used to locate excessive resistance in the starter system?

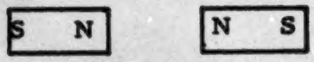
    a. Voltmeter
    b. Field rheostat
    c. Ammeter
    d. Load bank

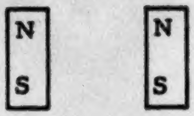
12. What is most likely to be wrong when the spark plug insulator nose is covered with gummy carbon?

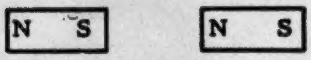
    a. Secondary voltage
    b. Ignition timing
    c. Heat range
    d. Spark gap

13. If two bar magnets are suspended by threads, which is a possible alinement that the magnets may take?

a. 

b. 

c. 

d. 

14. What is used to measure the amount that the ignition distributor cam rotates while the contact points are closed?

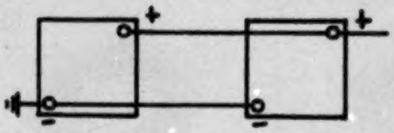
a. 6-inch ruler
b. Feeler gage
c. Timing light
d. Dwellmeter

15. Which should be the first step in ignition system troubleshooting?

a. Adjusting the distributor points
b. Testing the ignition switch
c. Cleaning the spark plugs
d. Testing the battery

16. Which circuit is connected properly to supply a 24-volt output from two 12-volt batteries?

a.



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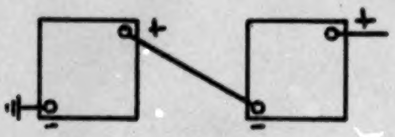

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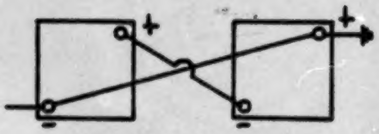

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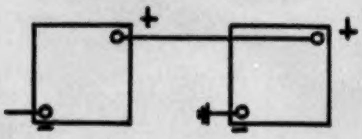


Note. - Questions 17 through 19 pertain to the M151 truck.

17. If the left headlight high beam does not light but the right one does, at which point should the circuit be checked first?

- a. Main light switch
- b. Headlight connector
- c. BO light connector
- d. Dimmer switch

18. Which item must be grounded with a jumper cable when it is removed for tests?

- a. Instrument cluster
- b. Light switch
- c. Trailer receptacle
- d. Ignition switch

19. The horn switch is connected between which two points?

- a. Horn and ground
- b. Ignition switch and horn
- c. Horn and circuit breaker
- d. Ignition switch and battery

20. Which item is interchangeable on all tactical vehicles?

- a. Battery-generator indicator
- b. Fuel gage sending unit
- c. Oil pressure gage
- d. Fuel pump safety switch

21. What is a difference between the M151 truck starter motor and most other military vehicle starter motors?

    a. Direction of rotation
    b. Operating voltage requirement
    c. Principles of operation
    d. Type of bearings used

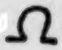
22. The purpose of the commutator bars and brushes in the starter motor is to

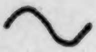
    a. produce a constant DC current output.
    b. engage the starter drive.
    c. cause continuous rotation of the armature.
    d. prevent damage to the starter after the engine starts.

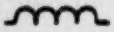
23. What term is usually used to describe an electrical circuit when its switch is in the OFF position?

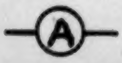
    a. Open
    b. Shorted
    c. Closed
    d. Grounded

24. Which symbol pertains to a unit that is used for reducing current?

a. 

b. 

c. 

d. 

25. Which is a difference between the leads for the LVCT ammeter and LVCT voltmeter?

    a. Type of insulating material
    b. Color
    c. Type of conductive material
    d. Size

26. What is indicated by a voltmeter reading of 0.6 volts between the battery ground and starter motor frame while the engine is being cranked?

    a. Field windings are open
    b. Electrolyte level is low
    c. Brush spring tension is weak
    d. Circuit has too much resistance

27. When installing the distributor, the number one cylinder should be placed on which stroke?

    a. Power
    b. Exhaust
    c. Intake
    d. Compression

28. Which instrument must be connected to the secondary circuit of the ignition system when it is used?

    a. LVCT
    b. Multimeter
    c. Timing light
    d. Dwellmeter

29. What should a battery be filled with if its liquid level becomes low due to natural causes?

    a. Sulfuric acid
    b. Distilled water
    c. Electrolyte mixture
    d. Peroxide solution

30. The magnetic lines of force in an ignition coil move across the secondary windings with the greatest speed when the

    a. centrifugal advance is maximum.
    b. breaker points open.
    c. centrifugal advance is minimum.
    d. breaker points close.

31. What produces the initial current flow in a DC generator?

   a. Electric magnet
   b. Generator regulator
   c. Residual magnetism
   d. Vehicle battery

32. What is the ampere-hour rating of a battery that can deliver 2.5 amperes for 20 hours?

   a. 8
   b. 17.5
   c. 22.5
   d. 50

33. What would result if the batteries were installed backward in a vehicle with an AC charging system?

   a. Circuit breaker would not close
   b. Alternator would reverse the battery charge
   c. Rectifier would be damaged
   d. Charging rate would be too high

34. What tester is used to measure ohms?

   a. Tachometer
   b. Hydrometer
   c. Multimeter
   d. LVCT

35. Which item is connected in series with the ignition contact points?

   a. Capacitor
   b. Spark plugs
   c. Secondary winding
   d. Primary winding

36. When making a generator output test with the LVCT, what is used to control the current?

   a. Load bank
   b. Ammeter
   c. Residual magnetism
   d. Regulator

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**Note.** - Questions 37 through 47 pertain to the M151 truck.

37. To check the input voltage to the distributor, in what position should the LVCT voltage switch be?

    a. 1-volt
    b. 10-volt
    c. 20-volt
    d. 50-volt

38. Which item must be removed in order to remove the starter motor?

    a. Vehicle battery
    b. Engine air cleaner
    c. Flywheel housing cover
    d. Transmission cover plate

39. Which item is used when measuring the amount of the fan and generator drivebelt deflection?

    a. Straightedge
    b. Spring scale
    c. Torque wrench
    d. Tension gage

40. Which part can be checked by an ohmmeter only?

    a. Fuel level gage
    b. Battery-generator indicator
    c. Water temperature gage
    d. Water temperature sending unit

41. What closes the fuel pump safety switch when the engine is running?

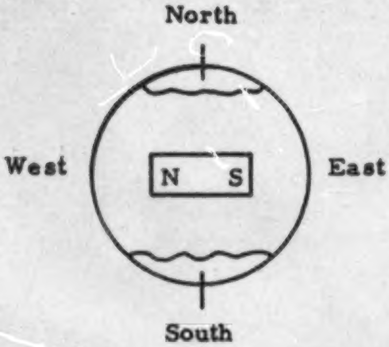
    a. Ignition current
    b. Starter motor current
    c. Engine oil pressure
    d. Fuel pump pressure

42. Which switch supplies current to the fuel pump only when cranking the engine?

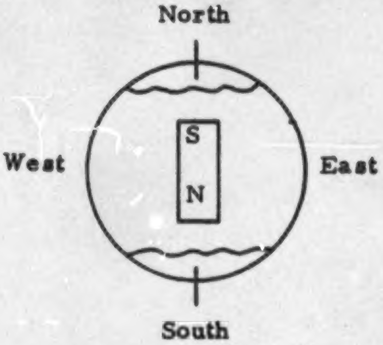
    a. Ignition
    b. Safety
    c. Starter
    d. Light

43. If a bar magnet is suspended on a thread so it is free to rotate, how will it aline itself in relation to the earth?

a.


North
West
N
S
East
South

b.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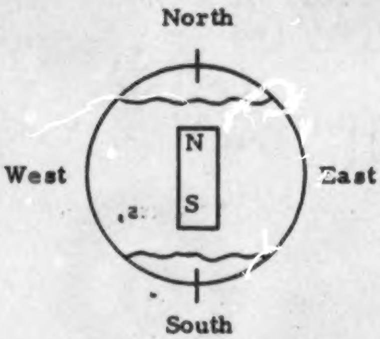
c.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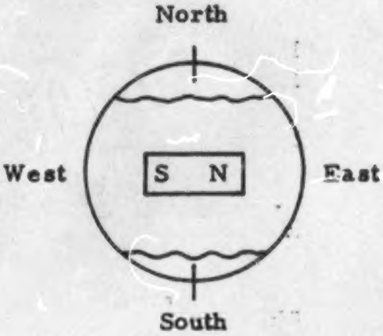
d.


North
West
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44. Which wrench is used to disconnect the generator-to-generator regulator wiring harness?

a. Box end
b. Crowfoot
c. Open end
d. Spanner

45. What type connection is used with batteries to increase the capacity?

a. Series
b. Parallel
c. Shunt
d. Short

46. When using the voltmeter, how is it connected?

    a. Directly to the power source
    b. In series with the load
    c. Directly to the load
    d. Parallel to the circuit

47. What is changed by varying the amount of current flow in a wire?

    a. Direction the magnetic lines of force move
    b. Atom structure of the wire
    c. Strength of the magnetic field around the wire
    d. Electrical polarity at the wire terminals

48. What is the actual specific gravity of a battery if the hydrometer reading is 1.230 and the electrolyte temperature is 120°?

    a. 1.350
    b. 1.246
    c. 1.214
    d. 1.110

49. If the 100-ampere alternator produces less than 27 volts, what should be adjusted?

    a. Carbon pile
    b. Rheostat
    c. Current regulator
    d. Rectifier

50. Which starter drive uses rollers to drive the pinion gear?

    a. Bendix
    b. Overrunning clutch
    c. Bendix Folo-Thru
    d. Double reduction